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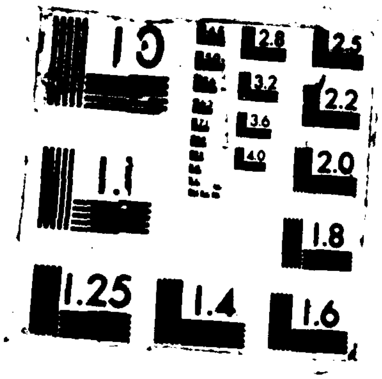
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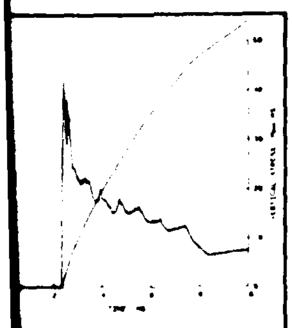

ANALYSIS OF DYNAMIC IN SITU BACKFILL PROPERTY TESTS

Report 1
A METHOD FOR REMOVING OSCILLATIONS AND DAMPING FROM DIAPHRAGM-TYPE STRESS GAGE RECORDS

by

Lynn Seaman

with contributions from

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A procedure for eliminating or minimizing the effects of stress gage frequency and damping has been developed. The method was applied to SE (diaphragm) stress gages used to measure soil stress during the passage of shock waves.

The purposes of this study were to understand how stress records of diaphragm gages are related to imposed stress histories and to develop a method for deriving the stress histories from the records. Two-dimensional wave propagation simulations of embedded gages were made to determine the effects of the gage frequency characteristics on the gage record; the results of these calculations showed that the gage filters the imposed stress like a single-degree-of-freedom oscillator would. Then a method was developed for deriving analytically a stress record corresponding to the response of an oscillator to an imposed stress history. This method was incorporated into an iterative procedure with which a user can construct a best estimate of a stress history acting on a diaphragm gage. This

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Plane shock waves
Processed stress histories
SDOF oscillator gage model

19. ABSTRACT (Continued).

estimate is not necessarily the soil stress that would have existed in the absence of the gage.

This record-processing procedure was used to compute stress histories for gages measuring vertical and horizontal stress in the DISKO-1 event executed by the US Army Engineer Waterways Experiment Station.

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PREFACE

The work described herein was performed by SRI International for the Structures Laboratory (SL), US Army Engineer Waterways Experiment Station (WES) under Contract No. DACA39-83-K-0002. It was sponsored by the Office, Chief of Engineers, US Army, as a part of Project No. 4A162719AT40, Task AO, Work Unit 024, "Ground Shock Prediction Techniques for Earth and Earth-Structure Systems." OCE Technical Monitor was Mr. R. L. Wight.

Dr. Lynn Seaman was the Principal Investigator for this study. Mr. Tom Cooper conducted the two-dimensional calculations that provided the basis for the approach. Ms. Bonnie Lew wrote and tested the original version of the computer program, RECFIT. Ms. Frances Lovell modified the program for ease of use interactively and augmented the plotting capability. Dr. Joseph S. Zelasko, Geomechanics Division (GD), SL, was the WES Contracting Officer's Representative. Dr. J. G. Jackson, Jr., was Chief, GD, and Mr. Bryant Mather was Chief, SL.

COL Dwayne G. Lee, CE, is Commander and Director of WES; Dr. Robert W. Whalin is Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
dynes per square centimeter	0.1	pascals
ergs	0.1	microjoules
feet	0.3048	meters
grams per cubic centimeter	1,000	kilograms per cubic meter
inches	25.4	millimeters
kips (force)	4.448222	kilonewtons
kips (force) per square inch	6.894757	megapascals
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter

ANALYSIS OF DYNAMIC IN SITU BACKFILL PROPERTY TESTS

A METHOD FOR REMOVING OSCILLATIONS AND DAMPING FROM DIAPHRAGM-TYPE STRESS GAGE RECORDS

I INTRODUCTION

The U. S. Army Engineer Waterways Experiment Station (WES) has conducted a series of small-scale, high explosive simulation tests on prepared soil beds to determine their dynamic uniaxial strain constitutive relations and the ratio (K_o) of horizontal to vertical stress. In these tests, a series of SE diaphragm stress gages were placed at a range of depths in the soil. A diagram of the experimental layout for the first of these tests[1,2] is shown in Figure 1. Many of the records showed severe oscillations near the wave front, causing uncertainties in the record interpretation. The sample records in Figure 2 illustrate these problems. In this study we wanted to eliminate these oscillations because they are mainly associated with the natural frequency of the gage and are not part of the actual soil stress history. Also we wanted to determine the actual arrival time and rise time of the wave front.

This effort was part of a larger study by SRI for WES to determine

The stress-strain relations for the soil in one-dimensional compression.

The stress path, or relation, between the axial and transverse stress.

The study had three major parts:

(1) Remove oscillations and other irregularities from the stress records and obtain the best estimate of the actual stress history experienced by the gage (the effort described in this report).

(2) Perform a Lagrangian analysis of the stress histories to obtain the stress-strain paths taken by the gages.[3]

(3) Modify the ONED one-dimensional wave propagation program[4] for simulating the stress-wave experiments, including the detonation.

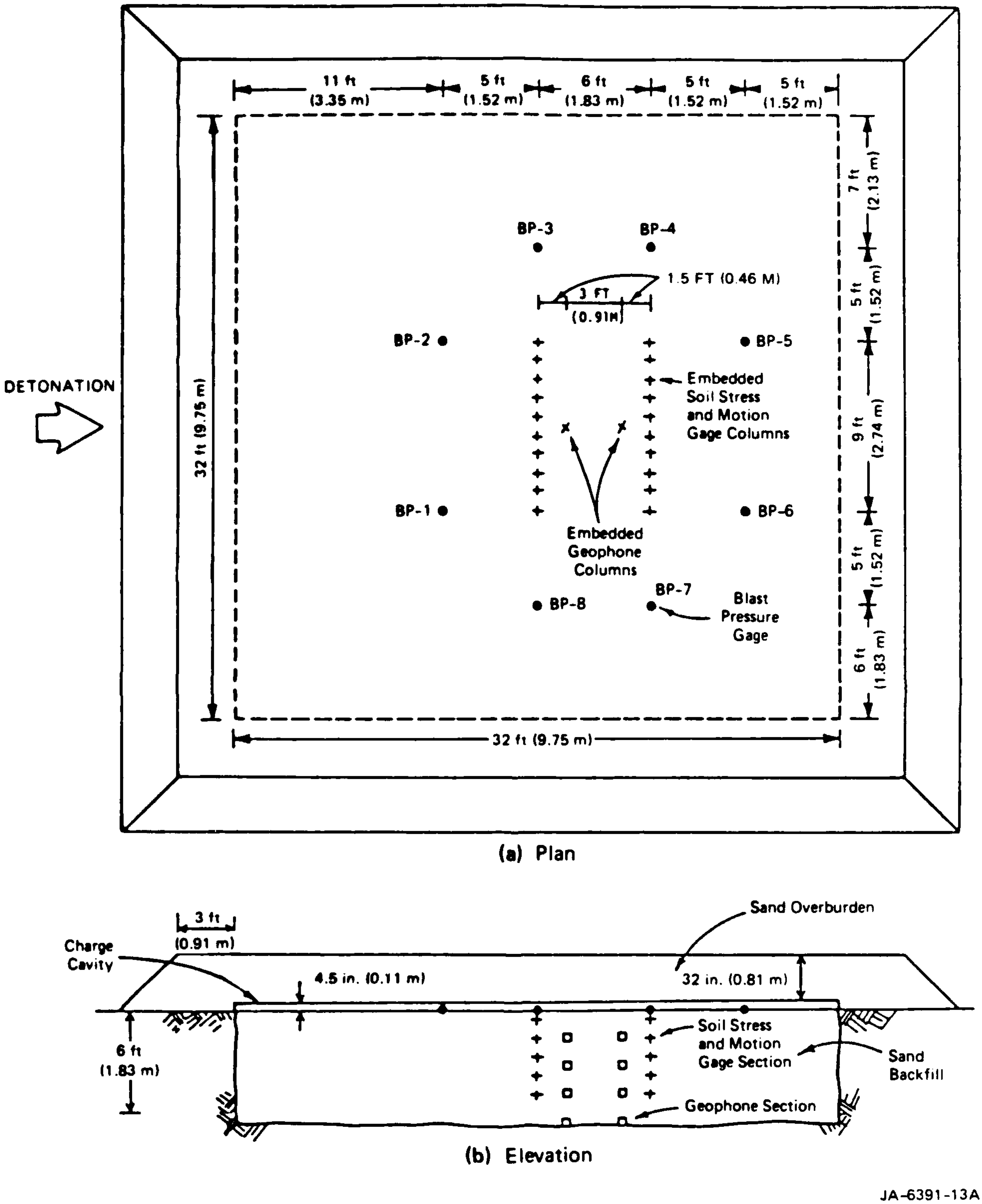

FIGURE 1 PLAN AND CROSS SECTION OF THE DISKO-1 SMALL-SCALE, HIGH-EXPLOSIVE SIMULATION TEST CONDUCTED BY WES

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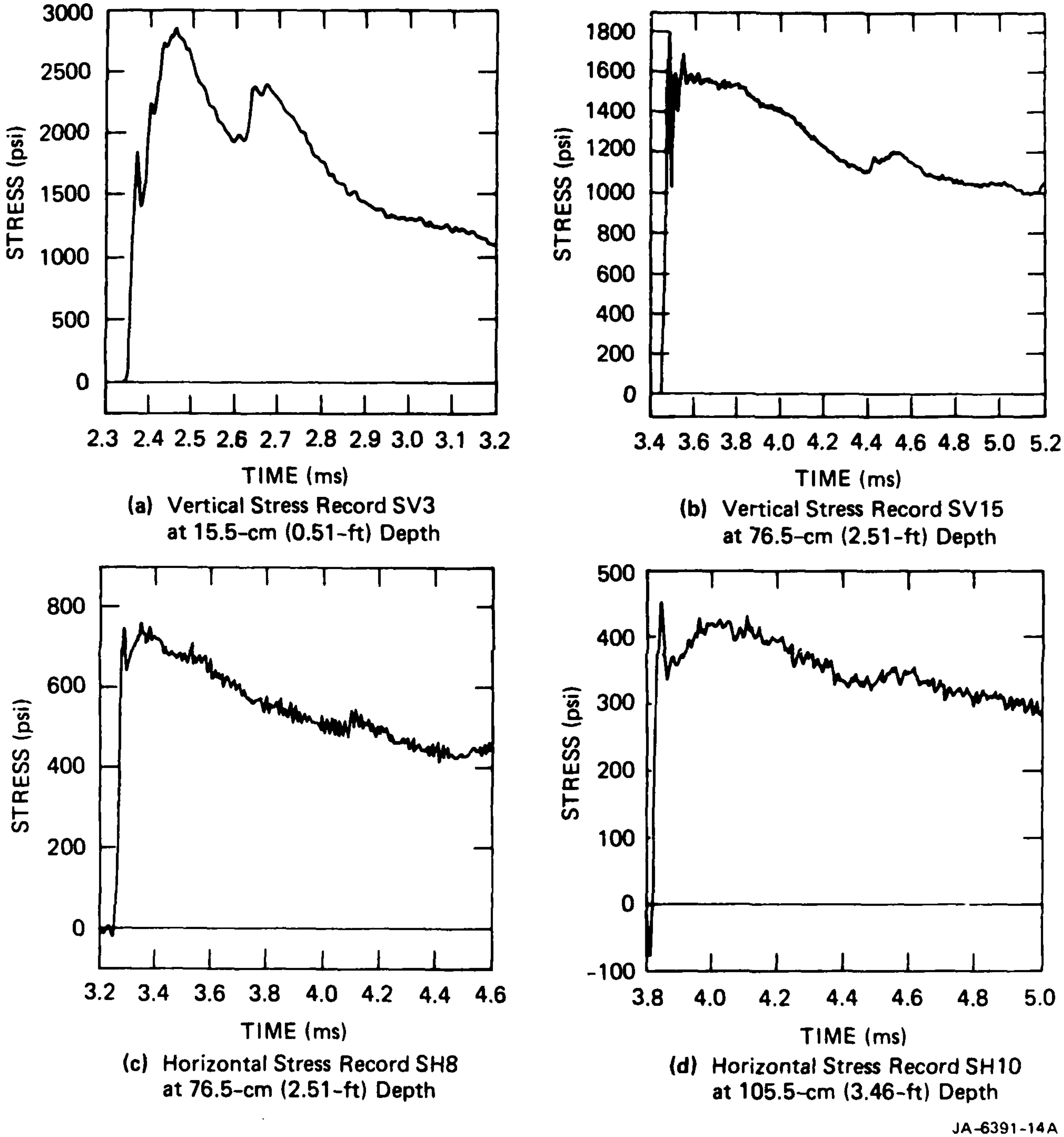


FIGURE 2 STRESS RECORDS OBTAINED FROM SEVERAL LRSE GAGES IN THE DISKO-1 EVENT

Because these three parts are quite distinct, a separate report was prepared for each part. However, all three parts constitute essential steps in the determination of soil properties from the gaged experiments.

First, it was necessary to determine the cause of the oscillations to develop a valid procedure for eliminating the oscillations. The cause was studied through two-dimensional simulations of the gage embedded in soil; these results are presented in Section II. Next, we devised a method for deriving a pseudo record based on an actual stress history plus the gage frequency and damping. This study, described in Section III, guided us in developing a procedure for determining the stress history acting on a gage from the stress record. Section IV provides a guideline for using the procedure and the computer program RECFIT. Results of sample calculations performed using the procedure are described in Section V.

It should be noted that the record processing described in this report does not necessarily provide histories of the true free-field stress. This procedure removes most of the effects of the gage frequency and damping and of the time for the wave to sweep across the gage. But the effects on the stress wave of the gage itself, packing materials around the gage, and the soil disturbance that occurred during placement of the gage are not accounted for. We hope to address these latter topics in further studies.

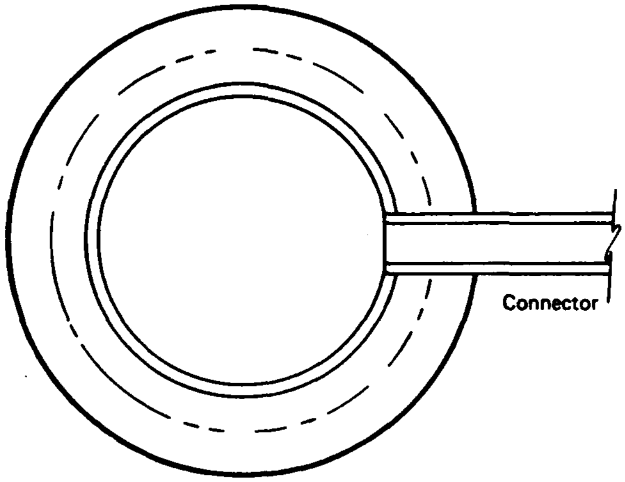
II TWO-DIMENSIONAL SIMULATIONS OF THE EMBEDDED SE STRESS GAGE

Two-dimensional finite-element simulations of the SE stress gages embedded in soil were conducted primarily to determine what caused the oscillations and other features of the stress records. We suspected that the record appearances were caused mainly by the frequency and damping characteristics of the gage and (for horizontal stress gages) the time for the stress wave to sweep over the gage.

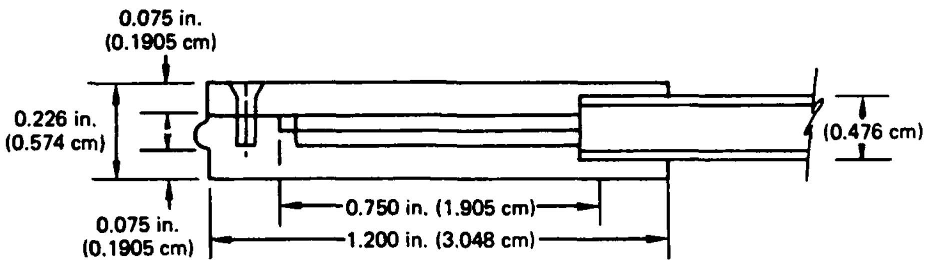
In this study calculations were made for a free gage, for a gage in soil receiving the vertical stress, and for an embedded gage receiving the horizontal stress (from a wave sweeping over the gage).

The free gage calculations were made to compare with the manufacturer's rated frequency (51 kHz)[5] to verify that our representation was sufficiently accurate. The gage considered has the form shown in Figure 3. Because of the thinness and unknown boundary conditions of the sensing element, this verification of the accuracy was important. The cell layout used for the calculation is shown in Figure 4. This coarse layout was necessary to allow for a reasonable calculation time for the later simulations of an embedded gage. The free gage shown in Figure 4 was loaded by a flat-topped stress pulse with an instantaneous rise. The response of the plate in the vicinity of the sensing elements (strain gages) is shown in Figure 5. The apparent frequency is about 37 kHz. This computed frequency should be compared with the manufacturer's listed frequency of 51 kHz and WES observations[2,5] of frequencies around 40 kHz. This match of the computational frequency to the actual frequency was considered adequate for our purpose with these computations. The damping shown in Figure 5 is about 4% of critical. This damping is caused by the artificial viscosity in the calculation.

The first embedded gage simulations were made for the situation in which the wave strikes the entire gage face simultaneously (vertical



(a) Plan of Bottom Half of Gage



(b) Cross Section of Gage

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FIGURE 3 CROSS SECTION OF AN SE STRESS GAGE FOR STRESS MEASUREMENTS BELOW 2000 psi (14 MPa)

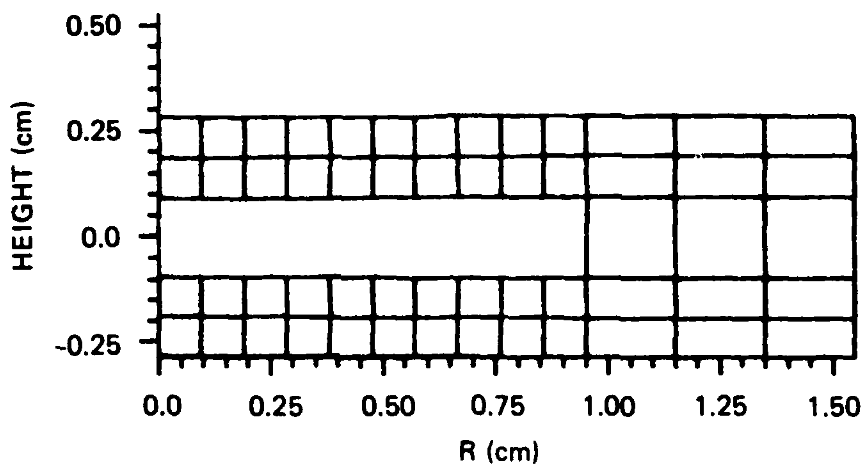

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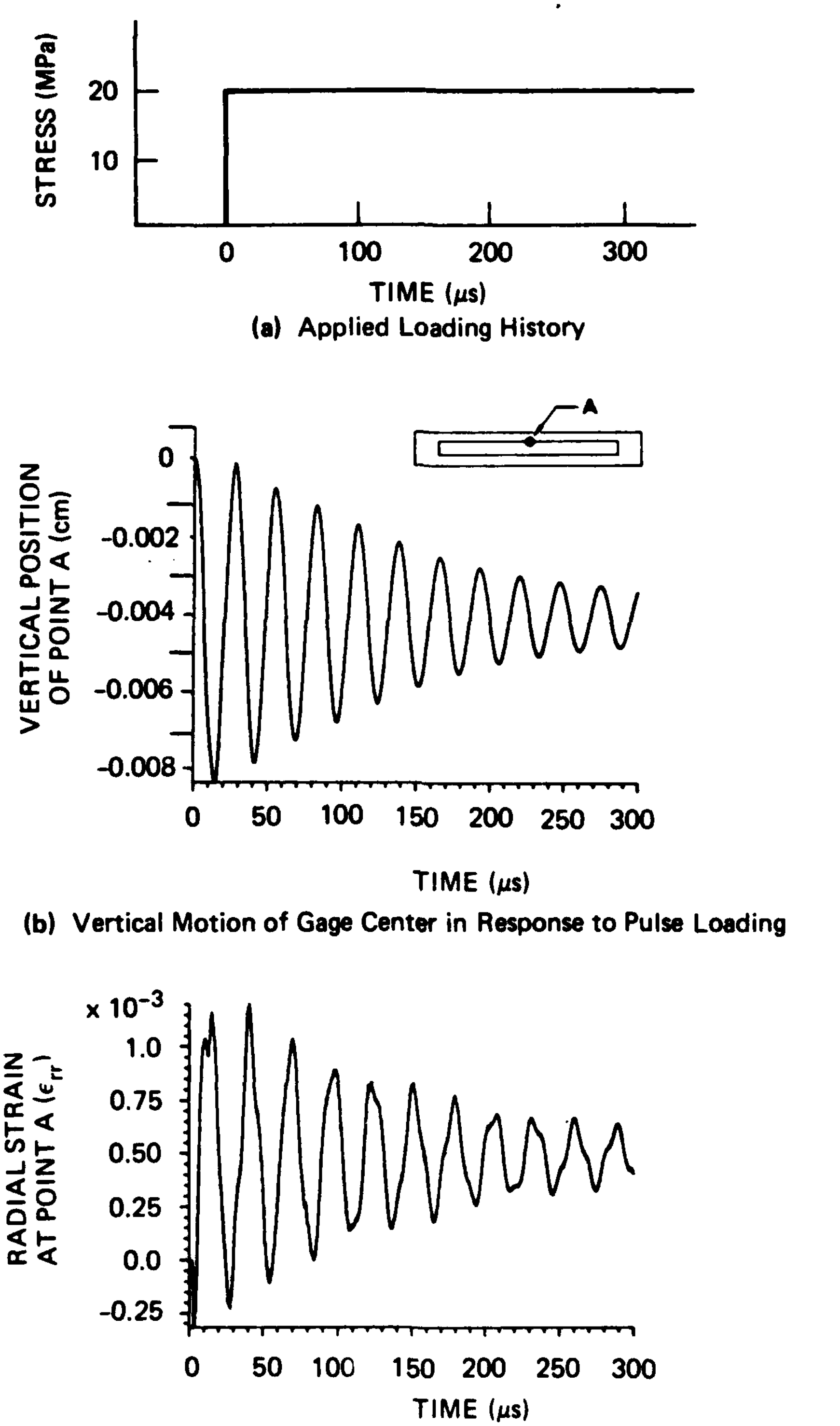
FIGURE 4 CELL LAYOUT USED IN SIMULATING THE FREE RESPONSE OF AN SE STRESS GAGE



(a) Applied Loading History

(b) Vertical Motion of Gage Center in Response to Pulse Loading

(c) Radial Strain at Strain Gage Location in Response to Pulse Loading

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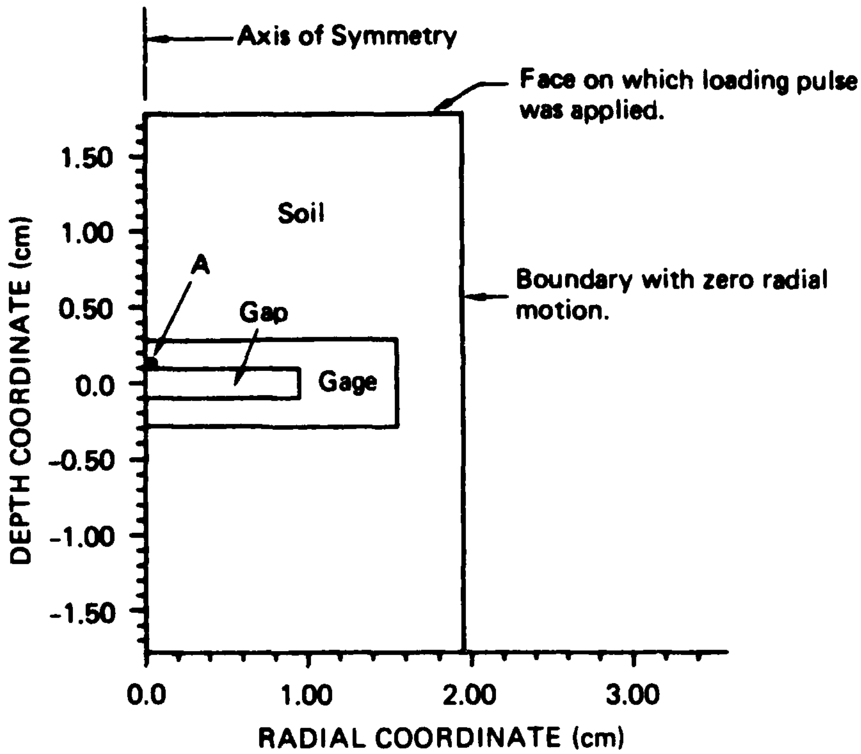
FIGURE 5 RESPONSE OF THE SE DIAPHRAGM STRESS GAGE TO A PULSE LOADING

stress case). Two configurations were used here: one with a small amount of surrounding soil and the second with a large amount. The first of these configurations is shown in Figure 6. The loading pulse with an amplitude of 20 MPa was applied to the top of the soil in the figure. The computed radial strain on the inner surface of this diaphragm is also shown in the figure. The frequency is approximately 29 kHz and the damping is 7 to 11% of critical damping.

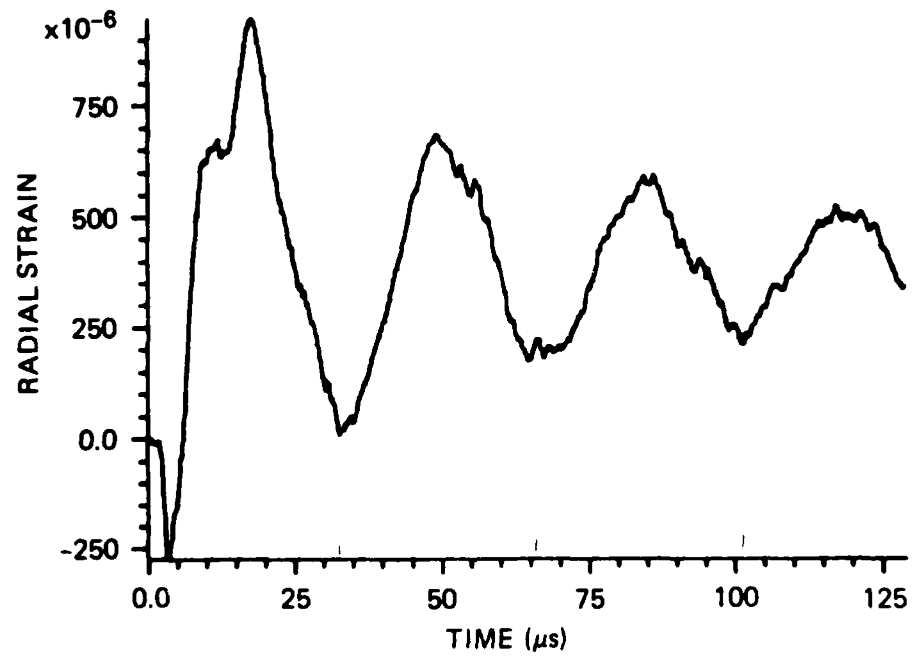
The second embedded gage calculation, in which a large volume of soil was used, is illustrated in Figure 7. As before, a step loading pulse with an amplitude of 20 MPa was applied to the top of the soil. In this case the apparent gage frequency is about 25 kHz and the damping varies from 14% near the wave front to nearly zero after several cycles. This computed record looks remarkably similar to field stress gage records. Comparison of the records in Figures 6 and 7 indicates that the computed behavior depends on the amount of soil included in the calculation. The result in Figure 7 is the more reliable result because the side and base boundary conditions (not present in the field) have less influence on the gage response. These results also indicate that embedment in soil reduces the gage frequency considerably (from 37 to 25 kHz) and increases the damping.

A similar series of simulations was performed for the wave sweeping over the gage face (horizontal stress configuration). In this case the simulations were performed under plane strain conditions. Here the gage is infinitely long in one plan dimension. Again, free vibration calculations verified that the simulated gage had approximately the correct natural frequency. The embedded gage calculations were performed only with the large mass of soil, as in Figure 7. The results showed a gradual rise of strain over 30 μs and almost no oscillations. We had expected a longer rise time corresponding to the time for the wave to sweep across the gage face.

The results of these two-dimensional simulations indicate that the SE stress gages can be simply treated as damped oscillators of finite size responding to stress waves with steep fronts. The rise time of the



(a) Configuration for the Embedded Gage Simulation



(b) Radial Strain at Point A on the Gage Sensing Element

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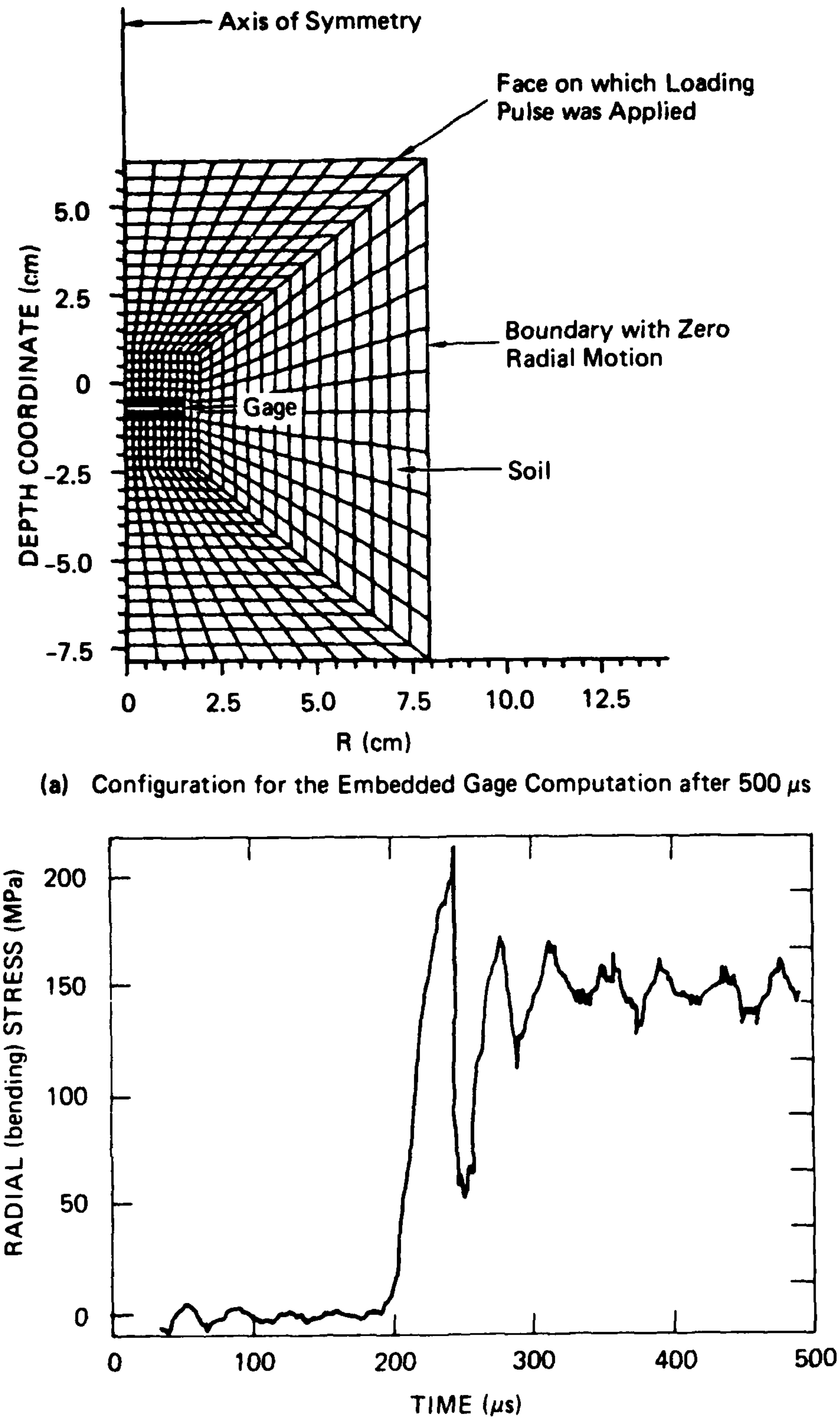
FIGURE 6 RESPONSE OF THE EMBEDDED SE GAGE TO A PULSE LOAD



(a) Configuration for the Embedded Gage Computation after 500 μs

(b) Radial Stress in the Center of the Diaphragm

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FIGURE 7 RESPONSE OF THE EMBEDDED SE GAGE IN A LARGE SOIL MASS

wave is less than the period of the gage, but we cannot yet estimate the rise time (estimates are made in Section V). From the simulations we can also expect that embedment of the gages will reduce the natural frequency and increase the damping. Because of the variability of the soil, we assume that the gages will each show somewhat different frequencies and damping characteristics in each experiment.

III THE RECORD PROCESSING PROCEDURE

The development of the record processing procedure began with the examination of the feasibility of such a procedure. The feasibility study led us to define a method and also to determine the conditions under which such a method is possible. Following this study, the basic analytical steps for this procedure were developed, as outlined in this section. A guideline for using the computer program embodying this procedure is presented in the next section.

A. Feasibility of a Record Processing Procedure

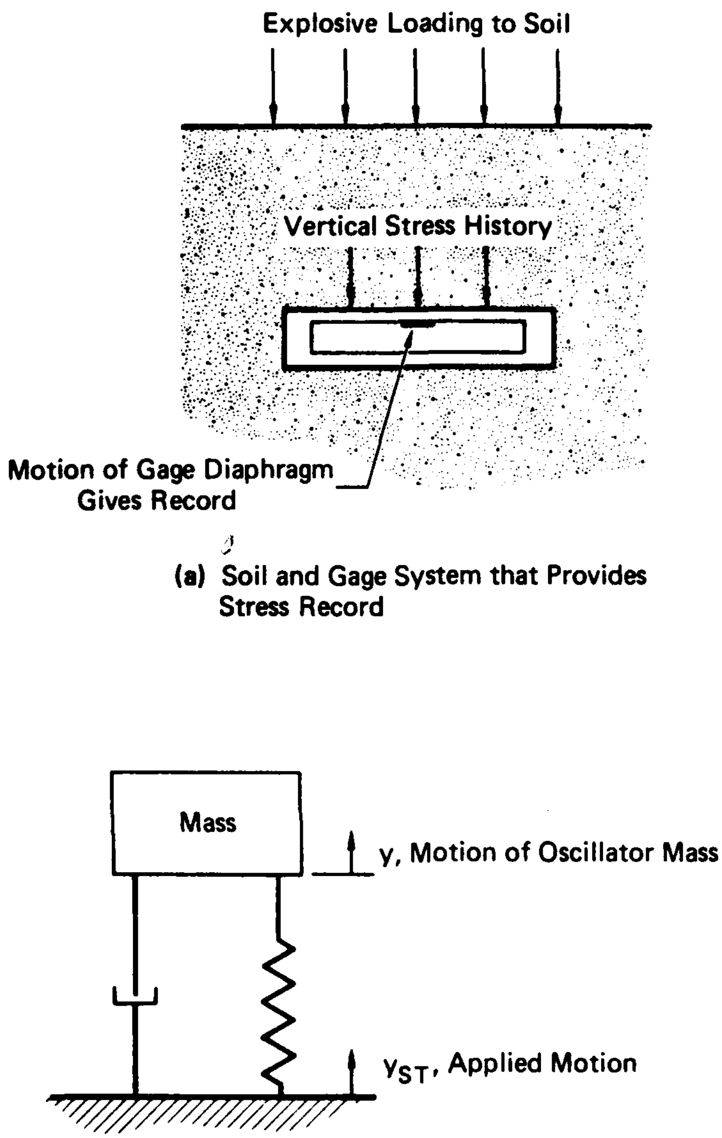
A feasibility study was undertaken to explore methods for removing the effects of the gage characteristics from the stress records. The following questions were considered:

(1) How can the oscillations be removed without also eroding the wave front? Standard smoothing techniques (e.g., a low-pass filter) would eliminate the oscillations, but they would also erode the wave front. Procedures for operating on the wave to remove specific frequencies are basically unstable because they are attempting to recover information that has been lost by the recording system.

(2) Can we detect the actual arrival time and rise time of the wave front?

(3) How can we develop a procedure for constructing the actual stress histories from the stress records?

To answer these questions, we began by representing the stress gage as a one-degree-of-freedom, damped oscillator, as indicated by the simulations in the preceding section. This idealization is shown in Figure 8. In Figure 8(a), the diaphragm of the gage moves in response to the applied stress; the diaphragm motion is measured by strain gages producing the "stress" record. The vertical stress history applied to the gage is the information of interest. Given the stress record, we are attempting to determine the applied stress history. In Figure 8(b), the



(a) Soil and Gage System that Provides Stress Record

(b) Damped Oscillator Representing Response of Soil Stress Gage

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FIGURE 8 IDEALIZATION OF THE SOIL-GAGE SYSTEM TO A DAMPED OSCILLATOR

foundation of the oscillator is moved in accordance with the applied motion y_{ST}. The motion y of the mass constitutes the record. Thus, we obtain y and attempt to reconstitute y_{ST}. The oscillator is a good representative of the soil-gage system to the extent that higher frequencies in the soil-gage system can be ignored and that the damping can be approximated by a linear viscous model.

Using the oscillator model, we began the study by analyzing simple wave forms, treating them as the true (free-field) stress histories, y_{ST}. Then we computed the response y of the damped oscillator to these stress histories and obtained pseudo stress records. By studying the relationships between the stress histories and pseudo records, we were able to answer the questions above.

Sample wave forms for stress histories are shown in Figures 9 through 11. These histories were applied as forcing functions to the oscillator representing the stress gage. For each wave form a pseudo record (motion of the oscillator) was computed by the analytical method of Appendix A. These stress histories have a bilinearly rising front to facilitate studying the sensitivity of the computed record to the wave front shape. Comparing these records in Figures 9 through 11 shows that the first stress peak is very sensitive to the rise time of the wave and to the stress amplitude at the break in the bilinear rise (the first node of the history). Thus, it appears that a record does contain enough information to determine both the rise time and the arrival time of the wave. These results are pertinent to the case where the stress history has the simple form of a series of linear segments with no more than two segments in the rise. We also made calculations with three segments in the rise, but these records did not give such a clear dependence of the points in the record to the wave form. (Our later experience in processing the DISKO-1 records suggested that two segments in the wave front are probably the maximum that should be considered.)

Later nodes in the sample stress histories were also altered systematically. Of course, shifts of a node in the history only alter points in the record at later times. We found that with about two nodes per

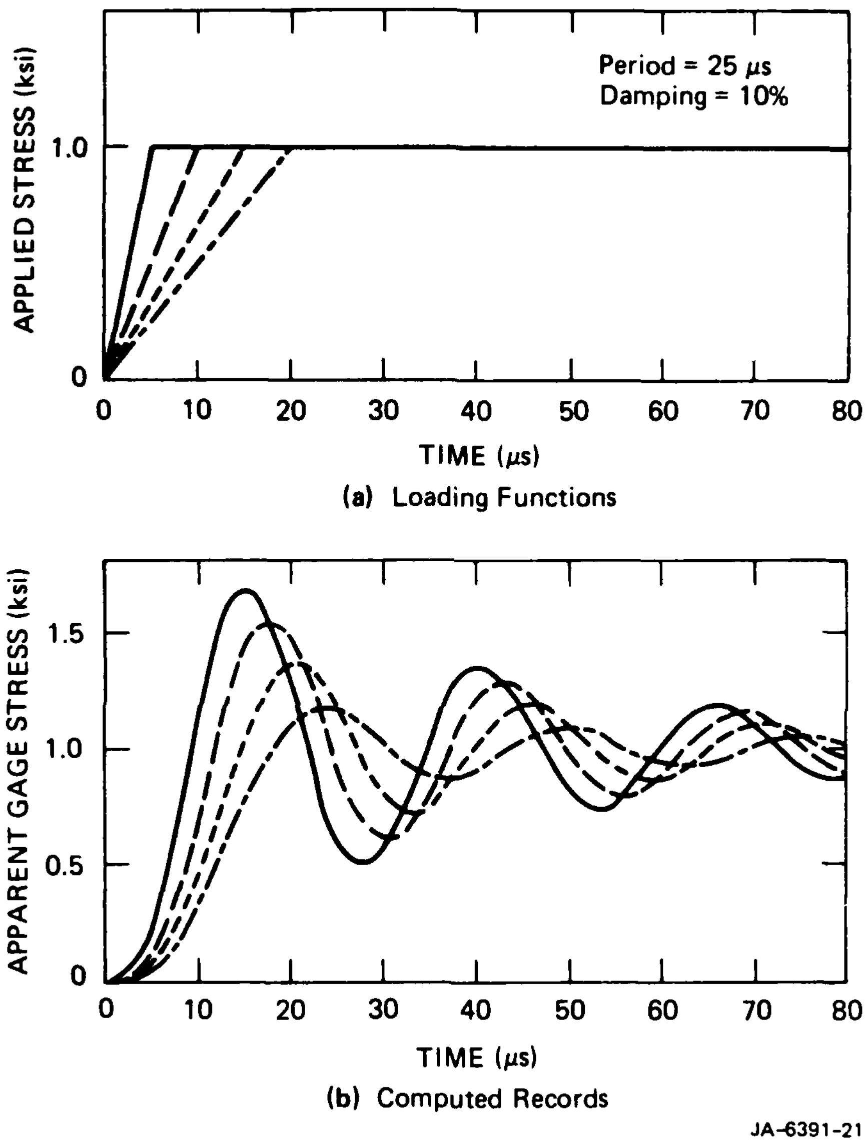
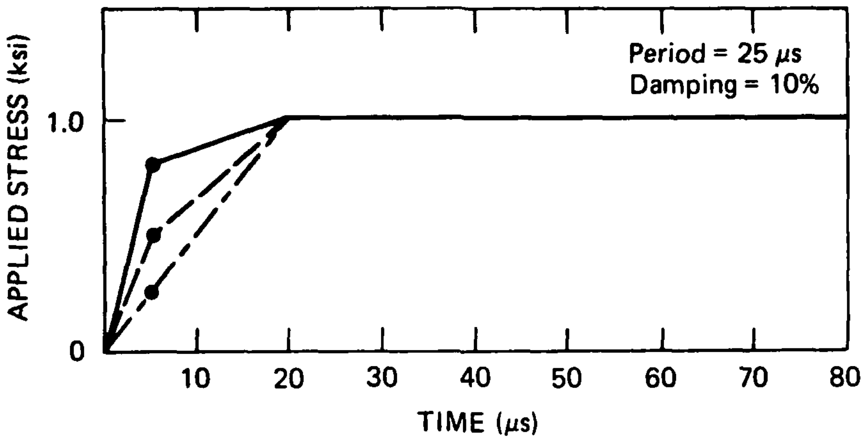
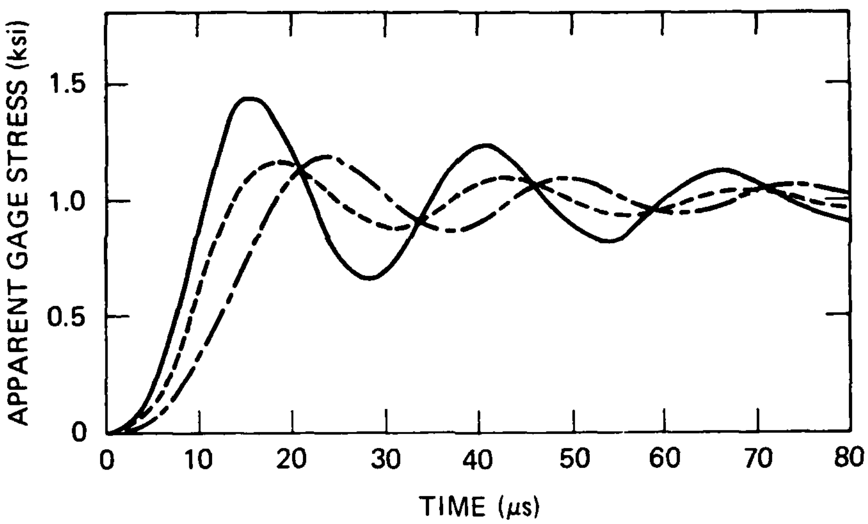


FIGURE 9 RESPONSE OF A ONE-DEGREE-OF-FREEDOM GAGE TO A SINGLE RAMP LOADING FUNCTION



(a) Loading Functions



(b) Computed Records

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FIGURE 10 RESPONSE OF A ONE-DEGREE-OF-FREEDOM GAGE TO A DOUBLE RAMP LOADING: SENSITIVITY OF THE RECORD TO THE AMPLITUDE OF THE FIRST NODE OF THE LOADING FUNCTION

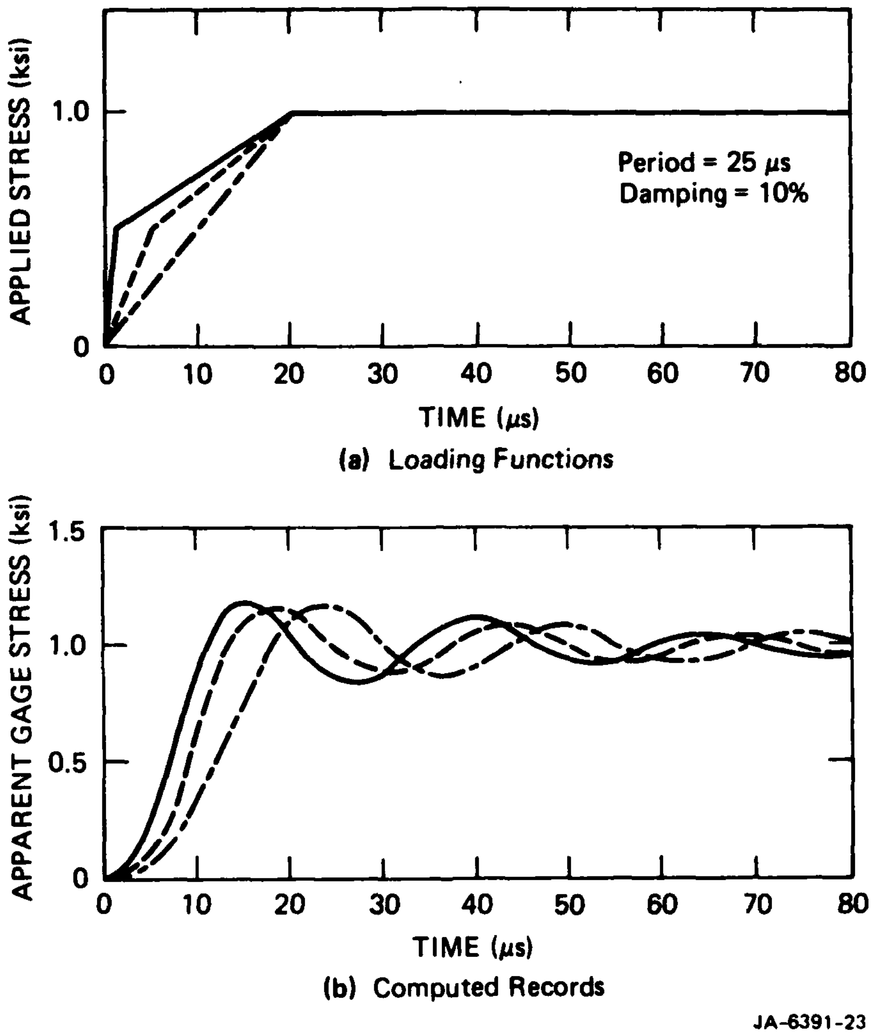


FIGURE 11 RESPONSE OF A ONE-DEGREE-OF-FREEDOM GAGE TO A DOUBLE RAMP LOADING: SENSITIVITY OF THE RECORD TO THE TIME OF THE FIRST NODE OF THE LOADING FUNCTION

period of the gage, there was a distinct effect in the record for each nodal shift.

Now we were able to answer the questions posed at the beginning of the section. The oscillations can be removed from the record if we restrict the shape of the generated stress history to linear segments with about two nodes per period. With this constraint we can determine the arrival time and rise time of the wave front.

The shape of the history can be found by starting with a history composed of linear segments with about two nodes per period. Beginning with the first nodes, the nodes can be shifted one at a time, and records constructed for each shift. The shifts should be made in a manner to cause the amplitude and time of the extrema of the computed record to match the extrema of the actual record. When the records match, the wave front of the constructed history will provide the arrival time and rise time of the wave. The remainder of the stress history can be constructed in the same fashion.

Thus, it appeared that an iterative procedure could be developed for processing the stress records and obtaining stress histories.

B. Development of the Procedure

The procedure outlined above contains the following steps: estimation of a trial stress history based on the stress record, computation of a pseudo record that would be obtained if the history were applied to the gage, revision of the trial history, and repetition of the computation and revision steps until the computed record matches the actual record satisfactorily. The analytical studies required to develop this procedure are outlined here. The following subsections include the derivation of the initial trial history, computation of the record, comparison of the pseudo record and actual record, and treatment of the horizontal gage effects.

1. Initial Estimate of the Stress History. Before a stress history can be constructed, some means must be developed to produce an

initial estimate. If the initial estimate is a good one, the further work required to modify the history is minimized. The method we used acts like a low-pass filter in eliminating oscillations or noise, and also eroding the shock fronts. Therefore, this initial estimate is accurate except at shock fronts.

The method of constructing an initial estimate was undertaken by examining the response of a damped oscillator to a step loading. The loading and response (record) are shown in Figure 12(a). The response Y was computed by integrating equation (A.2) in Appendix A.

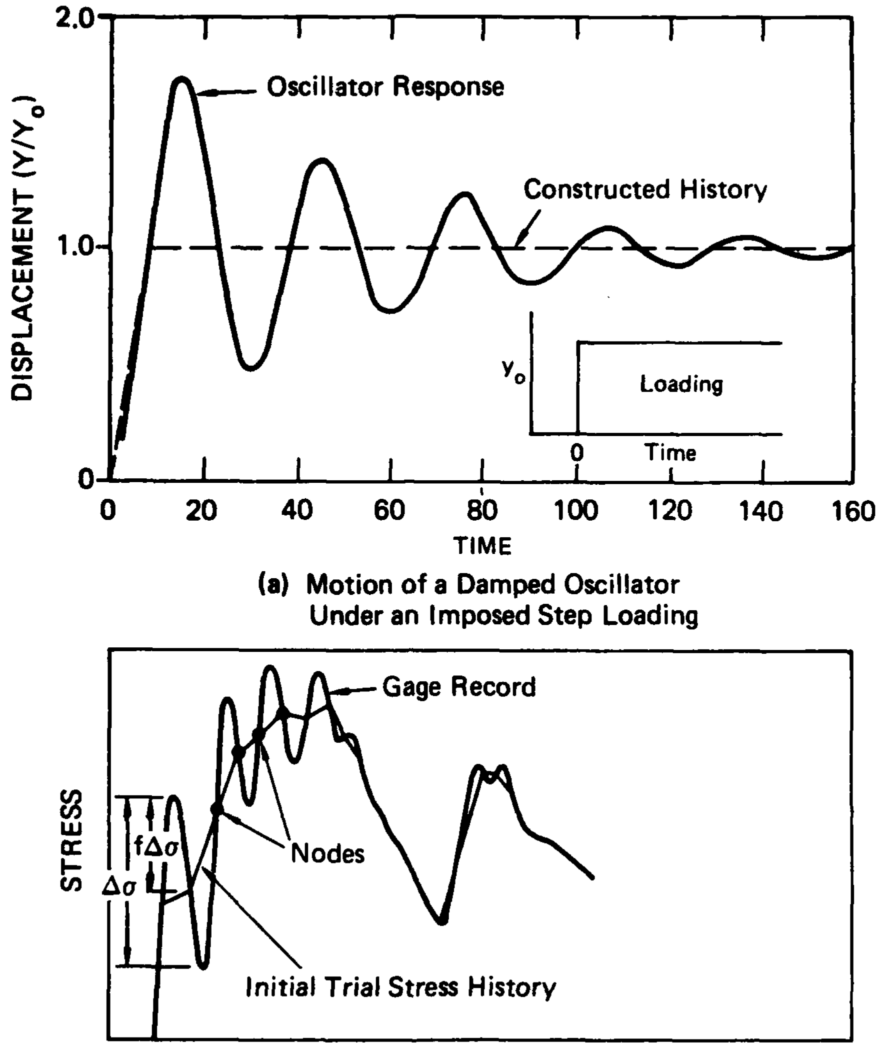
$$Y = Y_o \left[1 - e^{-\beta t} \left(\frac{\beta}{\omega_d} \sin\omega_d t + \cos\omega_d t \right) \right] \tag{1}$$

where Y_o is the amplitude of the step loading, β is the damping factor, t is time, and ω_d is the damped circular frequency. As shown in Figure 12(a), the peaks and valleys of this function are above and below the $Y = Y_o$ line. In fact, an average of the peaks and valleys would approximate the $Y = Y_o$ line. Hence, one could find the mid-point positions between successive peaks and valleys and connect these points to construct the estimated history. Such a construction is shown in Figure 12(b). Here the averaging factor f is not necessarily equal to 0.5. From equation (1) we can determine the correct averaging factor to provide a horizontal line at $Y = Y_o$ in Figure 12(a). The factor is

$$f = \frac{Y_o - Y_i}{Y_{i+1} - Y_i} = \frac{1}{1 + e^{-\pi\beta/\omega_d}} \tag{2}$$

where Y_i and Y_{i+1} are successive extrema of the function. With this procedure for constructing an estimated history, we obtained the dashed line in Figure 12(a). This constructed history has an eroded wave front, but the correct amplitude past the wave front.

The procedure for constructing an initial trial history in RECFIT follows closely the foregoing development. The user is asked to supply



(a) Motion of a Damped Oscillator Under an Imposed Step Loading

(b) Construction of a Trial Stress History by Connecting Points Between the Peaks and Valleys of the Stress Record

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FIGURE 12 IDEALIZED STRESS RECORD AND SAMPLE ACTUAL RECORD SHOWING METHOD FOR CONSTRUCTING INITIAL TRIAL STRESS HISTORY

the factor f ($f = 0.58$ for 10% damping). The midheight points (nodes) are chosen by RECFIT in a manner like that used in Figure 12(b). RECFIT does not maintain a constant f value, but allows f to gradually reduce toward 0.5.

For choosing the peaks and valleys of the record, RECFIT must be supplied with a time window size. An approximate window size is about one-half the period of the gage. RECFIT moves the window through the record, choosing successive extrema of the record and the appropriate midpoints.
If the record is monotonic within a window, the midpoint of the window is used. This procedure gives smoothed histories and is a good starting point for constructing an accurate wave front.

2. Computation of the Pseudo Record. For each trial stress history a pseudo stress record is computed numerically. The additional information required is the frequency and damping of the gage. The derivation of the numerical procedure is given in Appendix A.

3. Variance Between the Actual and Computed Record For this report, the variance between the two records is computed from

$$V = \sum_{i=1}^{N} (Y_{pi} - Y_{ai})^2 \tag{3}$$

where the sum is taken over the N time increments in the digitized (actual) record. Y_{pi} and Y_{ai} are the amplitudes at the same time t_i in the pseudo and actual records.

This variance is used in two parts of the calculation. First, this variance is used to compare the pseudo and actual records to aid in judging whether the trial stress history is sufficiently accurate. Second, this variance is used to determine the appropriate directions and amounts to shift the parameters of the trial stress history to bring the pseudo record into correspondence with the actual record. The first use is evident, so the rest of this subsection is devoted to the second use.

The parameters of the trial history that can be shifted to improve the match between the pseudo and actual records are the coordinates of

the first 3 or 4 points at the wave front [nodes in Figure 12(b)], plus the frequency and the damping of the gage. A variance calculation is used to aid the user in determining the best parameter to change, and the amount and sign of the change. The calculation has three steps:

- Shift each of the wave front and gage characteristic parameters by about 10% (one at a time), and construct the revised trial stress history:

$$P_i = P_{io} \pm \Delta_i \tag{4}$$

  where P_i and P_{io} are the revised and original values of one of the parameters, and Δ_i represents the 10% shift. For pressure or time values, $\Delta_i = 0.1 \max (|P_i - P_{i-1}|, |P_{i+1} - P_i|)$. With frequency and damping values, Δ_i is simply 10% of the current value of the parameter. Note that the complete calculation is performed for $+\Delta_i$ for each parameter, and then for $-\Delta_i$.

- Compute the pseudo record for each trial history and the variance V_i from the actual record.

- Compute the derivative D_i of the parameter with respect to the variance. A useful numerical approximation for this derivative is

$$D_i = \frac{V_o \Delta_i}{V_o - V_i} \tag{5}$$

With the derivative in equation (5), we can compute the amplitude of the parameter required to produce zero variance, assuming that the variance is a linear function of the parameter. This amplitude is

$$P_{id} = P_{io} + D_i \quad . \tag{6}$$

This series of calculations is performed each time the user is provided with a pseudo record and a variance. Thus, he is guided toward the selection of the next trial history.

Table 1 shows the results of such a variance calculation. Here the

variances V_i can be compared with $V_o = 3.101 \times 10^5$, listed below the Table. In improving our trial histories, we noticed which parameter changes led to significant variance changes. In the Table, the change in T_1 has the most important effect on the variance, so we chose it for changing. Then we looked to the derivatives to find how much to change the parameter we had identified. We could use the 10% change indicated in the Table, or possibly a 50% change, but for large changes we run the risk of jumping over the best solution. In all cases we changed only one parameter at a time and used judgment in deciding how much change to make.

4. Horizontal Stress Records. Some of the SE stress gages used in DISKO-1 were oriented to be sensitive to the horizontal stress during the event. The experiment was designed to be essentially a uniaxial strain experiment; hence, the ratio of horizontal stress S_H to vertical stress S_V was expected to provide a dynamic value of K_o[1,2]:

$$K_o = S_H/S_V \tag{7}$$

The factor K_o and both stresses can vary through the loading time. Therefore, it is important to obtain histories of S_H and S_V at the same location, with similar rise times, and with gage and recording characteristics removed from the records. The horizontal stress gage records contain two effects that must be accounted for: the gage frequency characteristics and the gradual sweeping of the stress wave over the gage face. The gage frequency effects are like those for the vertical stress gages, and the method for treating these effects was outlined above. Here a method is developed for handling the sweeping wave effect. With a computational procedure to treat both these effects, we anticipated obtaining reasonable estimates of the actual horizontal stress histories.

When a wave sweeps across the face of a horizontal SE stress gage, the record shows a gradual rise of about 40 μs. Samples of such records

Table I

PARAMETERS OF THE STRESS HISTORY, PARAMETER SHIFT, AND VARIANCES FROM THE ACTUAL STRESS RECORD

Parameter	Nominal Value P_{io}	Shift of the Parameter Δ_i	Variance of History V_i
T_0	3.787×10^{-3}	1.700×10^{-6}	3.098×10^{5}
T_1	3.804×10^{-3}	2.700×10^{-6}	2.779×10^{5}
T_2	3.831×10^{-3}	2.700×10^{-6}	3.283×10^{5}
T_3	3.858×10^{-3}	2.700×10^{-6}	3.336×10^{5}
Y_1	3.759×10^{1}	2.211×10^{1}	3.296×10^{5}
Y_2	1.835×10^{2}	2.211×10^{1}	3.060×10^{5}
Y_3	3.925×10^{2}	2.090×10^{1}	2.956×10^{5}
β/ω	0.1	0.01	3.079×10^{5}
$2\pi/\omega$	3.000×10^{-5}	3.000×10^{-6}	3.090×10^{5}

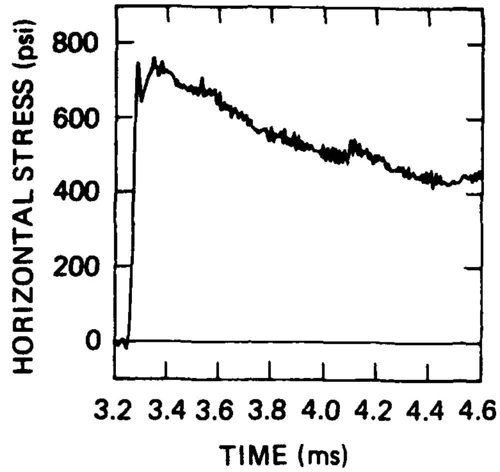
Notes: Y_i, T_i are coordinates of the i^{th} point of the trial stress history
β/ω is the fraction of critical damping
$2\pi/\omega$ is the period of the gage
Initial variance V_o is 3.101×10^5

are shown in Figures 2(c) and 2(d). This gradualness reflects the fact that the record is related to the central deflection of the gage plate and thus to some average of the stress applied to the gage face (see Figure 13). To analyze this gradual loading, we considered the response of a clamped circular elastic plate to a step wave that sweeps over the plate. Timoshenko[6] has given an expression for the central plate deflection for a load at any point on the plate. The differential deflection for a stress $\bar{p}$ applied on a differential area dA is

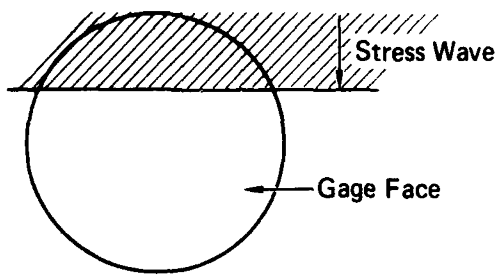
$$dW = \frac{\bar{p}}{8\pi D}\left(b^2 \ln \frac{b}{a} + \frac{a^2 - b^2}{2}\right) dA \qquad (8)$$

where b is the radius to the loaded area as shown in Figure 13(c), a is the radius of the plate, and D is the bending stiffness of the plate. As shown in Appendix B, equation (8) can be integrated to obtain the plate deflection under a sweeping stress wave. Thus, for a known stress history, a stress record that accounts for the sweeping effect can be constructed. This sweeping effect was incorporated into RECFIT for processing the horizontal stress records.

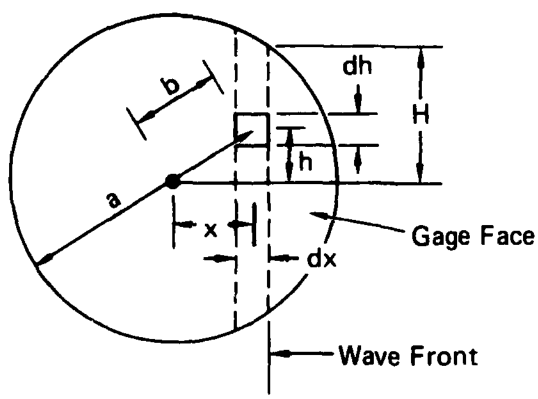
Some of the steps in the horizontal stress gage calculation are illustrated schematically in Figure 14. Figure 14(a) is the trial history with the nodes that can be moved to improve the match of the records in Figure 14(c). Figure 14(b) contains the record produced by passing the trial history through the smearing process just described above. This smearing associated with the sweeping wave is handled in a subroutine called HORGAGE. Next the smeared record is applied to the damped oscillator, and the pseudo stress record is computed. This second computation occurs in the RUNG subroutine and is described in Appendix A.



(a) Stress History from Horizontal Stress Gage SH8



(b) Wave Sweeping over a Horizontal Stress Gage (Gage Element is Vertical)



(c) Nomenclature for Analysis of the Response of the SE Diaphragm Gage to a Sweeping Wave

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FIGURE 13 HORIZONTAL STRESS RECORD AND NOMENCLATURE FOR ANALYSIS OF THE SWEEPING WAVE

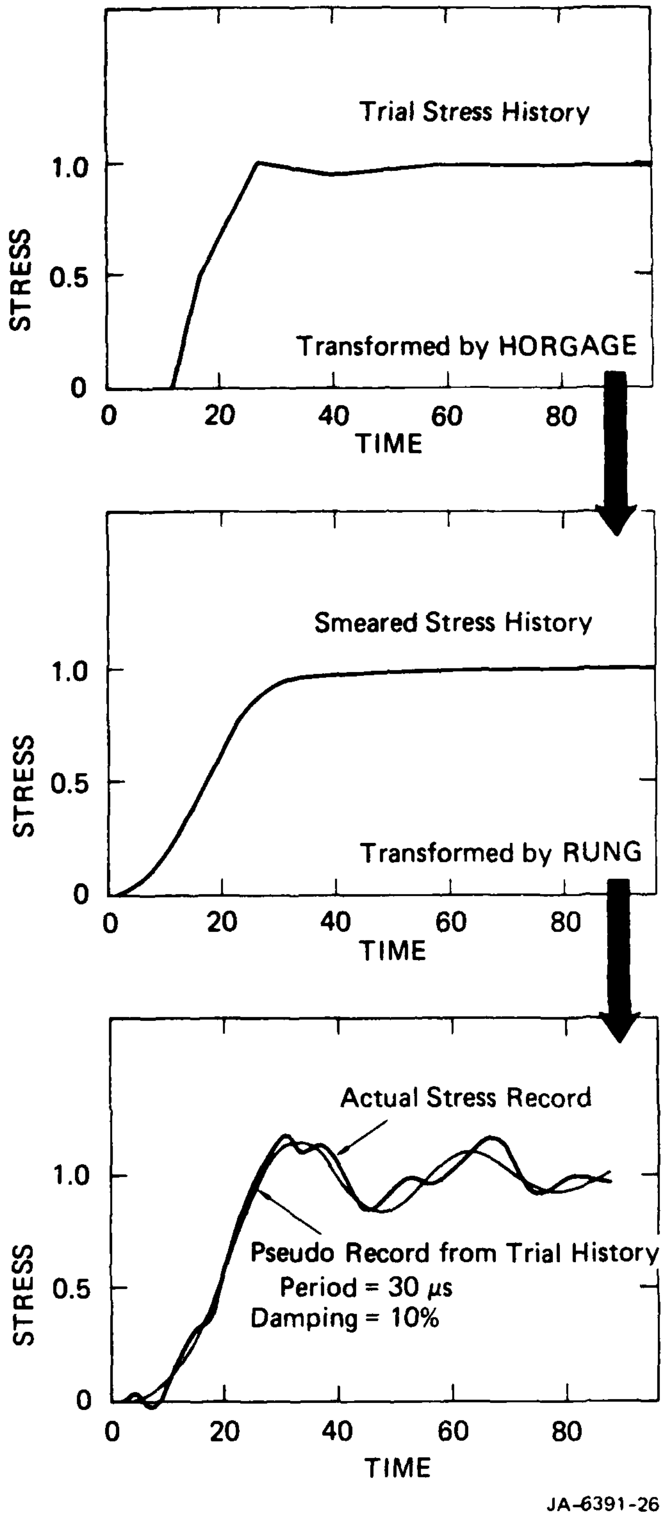


FIGURE 14 SEQUENCE OF CALCULATIONS TO CONSTRUCT A PSEUDO GAGE RECORD FOR A HORIZONTAL STRESS GAGE

IV GUIDELINE FOR USING THE RECORD PROCESSING PROCEDURE AND RECFIT

A procedure was constructed for deriving a stress history from vertical and horizontal stress records. (Vertical stress here means the stress in the direction of wave propagation and horizontal means transverse to this direction.) These records are presumed to be obtained from gages whose frequency and damping characteristics have modified the applied stress in forming the records. The stress history is taken here as the actual stress occurring on the gage face. The procedure consists of a computer program, RECFIT, and a method for using it. The result is a stress history that, when imposed on the gage (or on a damped oscillator with the gage characteristics), will provide a record that matches the actual record.

A. Outline of the Procedure

In using the RECFIT program the user must provide a digitized gage record. Then through a series of trials, the user constructs a stress history that will produce the matching stress record. RECFIT computes a stress record for each trial history and also guides the user in the choice of alterations to make at each step.

For undertaking the record construction RECFIT has these elements:

(1) An initial smoothing process which automatically selects a starting estimate of the stress history imposed on the gage.

(2) A method of computing the gage record in response to any imposed stress history. The computed record is compared with the actual record and the statistical variance is obtained.

(3) Provision for incrementally changing one at a time each coordinate of the trial history, plus the period and damping; constructing a gage record for each altered trial history; and computing the variance from the actual record. These variances can guide the user to

choose subsequent improvements in the trial stress history.

(4) Means for plotting the histories and records and for storing the final stress history.

These elements of the program are explained below using a sample calculation.

B. Input and Sample Calculation

In the following example, the record from a horizontal stress gage from DISKO-1 is processed. The RECFIT program is interactive, so a fixed appearance cannot be prescribed for the input file. During the calculation the user is asked for data or decisions at several steps. As a guide to the user, a listing is given below of a possible sequence of questions and responses.

The following sample calculation contains the questions and data provided by the computer, the user's responses, a prepared data file, plus notes on the computational process. These four types of information can be distinguished by the indicators at the left of each line:

```
Blank, written by the program,
->     to be written by the user, and
1      for input from file 1, the stress gage data.
```

Note: Notes on the process are written in lower case, and are filled to the left of the line.

The interactive session begins with the message:

```
    *****  RECFIT, AN INTERACTIVE RECORD FITTING PROGRAM

    ENTER FILE NAME CONTAINING ORIGINAL DATA

  ->  SH10.DAT
```

Note: In addition to the foregoing two lines read from file 1, labelled SH10.DAT, are the following lines:

```
1  5000  2.00000000E-06

1   9.16333570E+00  2.29083390E+00  4.58166780E+00  6.87250180E+00  1.37450040E+01
1   1.37450040E+01  1.14541700E+01  6.87250180E+00  0.00000000E+00 -2.29083390E+00
1  -4.58166780E+00 -2.29083390E+00 -2.29083390E+00  0.00000000E+00  0.00000000E+00
1      etc.
```

```
1
1    3.16135080E+02  3.18425910E+02  3.23007580E+02  3.34461750E+02  3.43625090E+02
1    3.39043420E+02  3.39043420E+02  3.32170920E+02  3.27589250E+02  3.20716750E+02
1    3.25298420E+02  3.27589250E+02  3.25298420E+02  3.32170920E+02  3.32170920E+02
```

Notes: The input from file 1 has the following form:
First line: 60 alphanumeric characters.
2nd line: I5 for NPT the number of points, and E16.8 for the time step DT.
3rd and subsequent lines are in the format 5E16.8.

```
    IS THIS A RESTART RUN?
 -> N
```

Notes: For a restart run, enter Y. The restart data are on file 3. These restart data are the trial stress history parameters obtained during a previous series of calculations.

```
    FILE CONTAINING DATA IS IN FOLLOWING FORM:

       TITLE   (A60)
       NO. OF POINTS  (I5), TIME INCREMENT  (E16.8) INITIAL TIME  (E16.8)
       AMPLITUDE  (5E16.8)

    IS THAT CORRECT?
 -> Y
        27-JUN-86 -1-SAND 1-3-7    STRESS - PSI      SH 10
    NPT = 5000 DT = 2.00000E-06 T(I) = 0.00000E+00

    ENTER PERIOD OF THE GAGE (SEC) AND FRACTION OF DAMPING
     EXAMPLE:  2.5E-5,0.05
 -> 4.0E-05, 0.2

    ARE THE DATA FROM A HORIZONTAL GAGE?
 -> Y

    DO YOU WANT A PLOT OF ACTUAL RECORD AND TRIAL RECORD?
 -> Y

    XMIN, XMAX =     0.000E+00  0.000E+00  WANT TO CHANGE THEM?
 -> Y

    ENTER XMIN,XMAX
 ->    3.500E-03   5.500E-03
```

Notes: At this point a figure, such as Figure 15, is plotted. In this figure the oscillatory history is the original record, and the smoothed one is the initial trial history obtained in the program by taking the mid-points of the oscillations.

```
    WANT TO MODIFY RECORD?
```

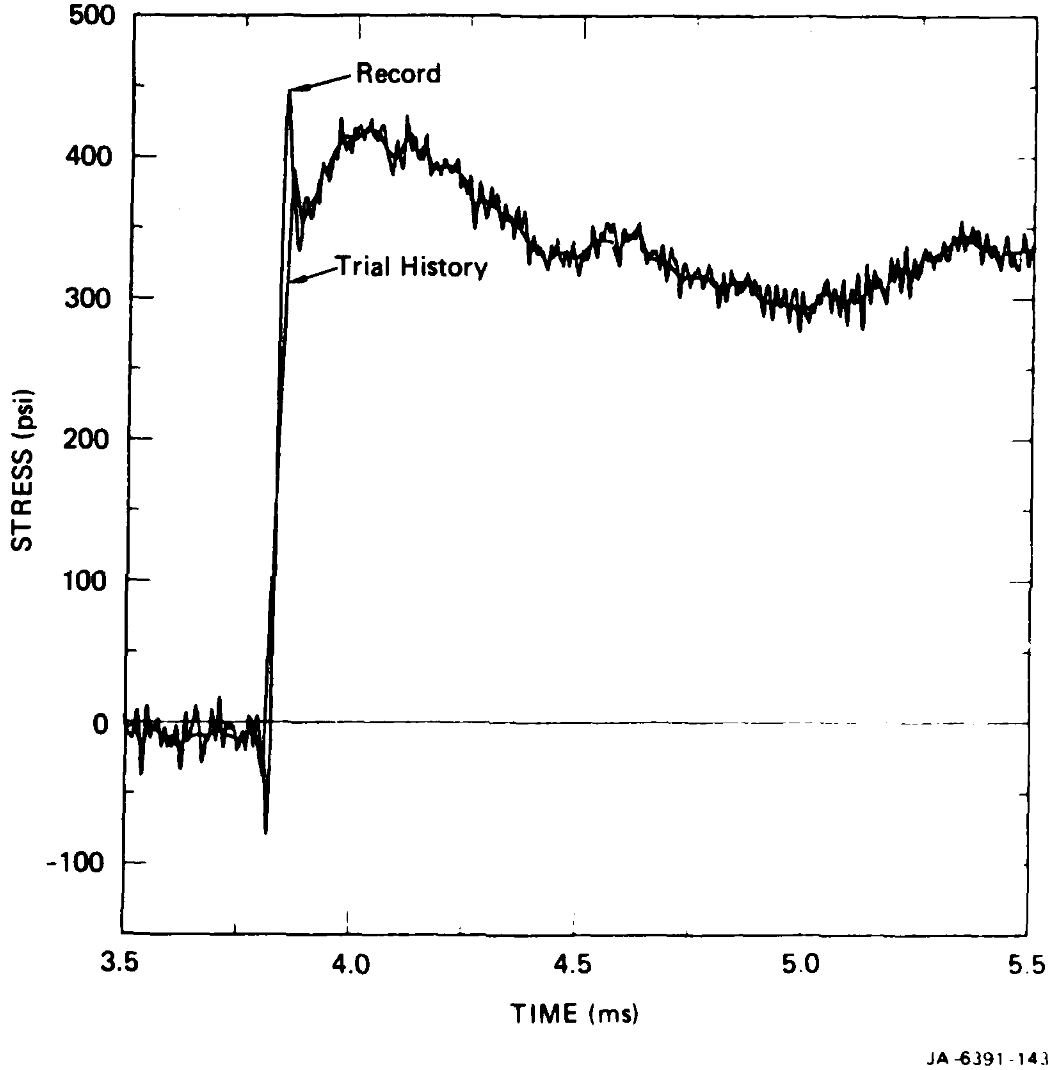


FIGURE 15 MEASURED STRESS RECORD FROM HORIZONTAL GAGE SH10 IN DISKO-1 WITH INITIAL TRIAL STRESS HISTORY

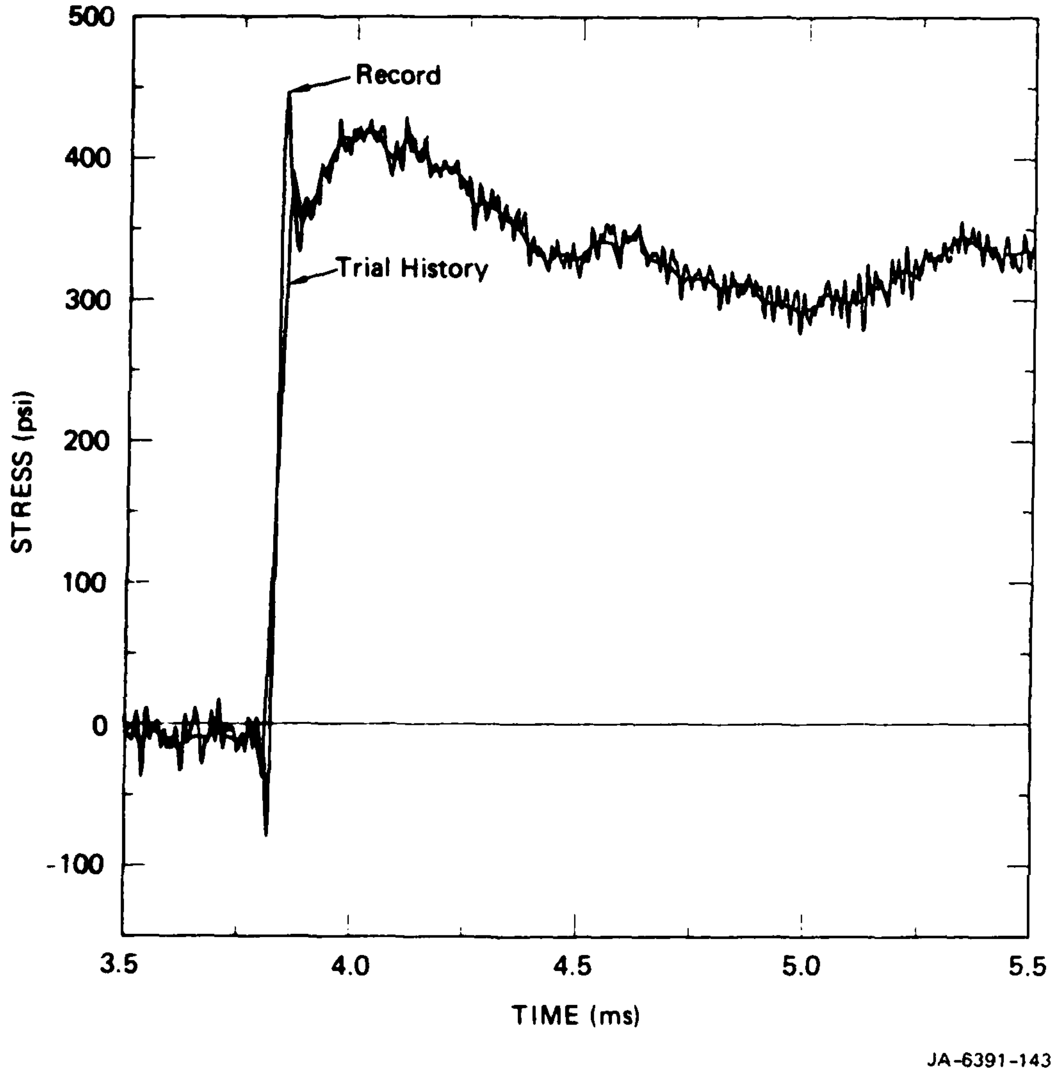


FIGURE 15 MEASURED STRESS RECORD FROM HORIZONTAL GAGE SH10 IN DISKO-1 WITH INITIAL TRIAL STRESS HISTORY

```
   -N- EXITS WITHOUT WRITING ANY OUTPUT FILES
-> Y
  ENTER GAGE RADIUS (CM)
-> 0.95
  ENTER SOUND SPEED (CM/SEC)
-> 5.6E+04
```

Notes: The sound speed of the soil is used to compute the crossing time of the gage face.

```
   WANT TO PLOT ACTUAL RECORD AND STRESS HISTORY
   OBTAINED FROM HORIZONTAL GAGE DATA?
-> Y

   XMIN, XMAX =    3.500E-03  5.500E-03  WANT TO CHANGE THEM?
-> Y

   ENTER XMIN,XMAX
->    3.800E-03   5.000E-03
```

Notes: Now a plot like Figure 16 is generated. Here the original record is the oscillatory solid curve and the dashed line is the response obtained by passing the trial history (from Figure 15) through the smearing process.

```
   WANT TO PLOT STRESS RECORD, ESTIMATED HISTORY,  AND COMPUTED?
-> Y
```

Notes: Here the stress history obtained by computing the response of the gage (or an equivalent one-degree-of-freedom system) to the smeared history is plotted. Not shown.

```
   XMIN, XMAX =    3.800E-03  5.000E-03  WANT TO CHANGE THEM?
-> N

   WANT TO EXAMINE AND MODIFY RECORD IN DETAIL?
   -N- WRITES OUTPUT FILE AND PREPARES TO EXIT
-> Y

   WANT TO PLOT STRESS RECORD, ESTIMATED HISTORY,  AND COMPUTED?
-> Y

   XMIN, XMAX =    3.800E-03  5.000E-03  WANT TO CHANGE THEM?
-> Y

   ENTER XMIN,XMAX
->    3.800E-03   3.900E-03
```

Notes: Here a plot like that in Figure 17a is generated showing a small portion of the records, the shock front in the present case. The solid line is the original record, the points are the trial history, and the dashed line is the computed response of the gage to this trial.

```
   WANT TO REPLOT WITH DIFFERENT SCALES TO EXAMINE A SMALL REGION?
```

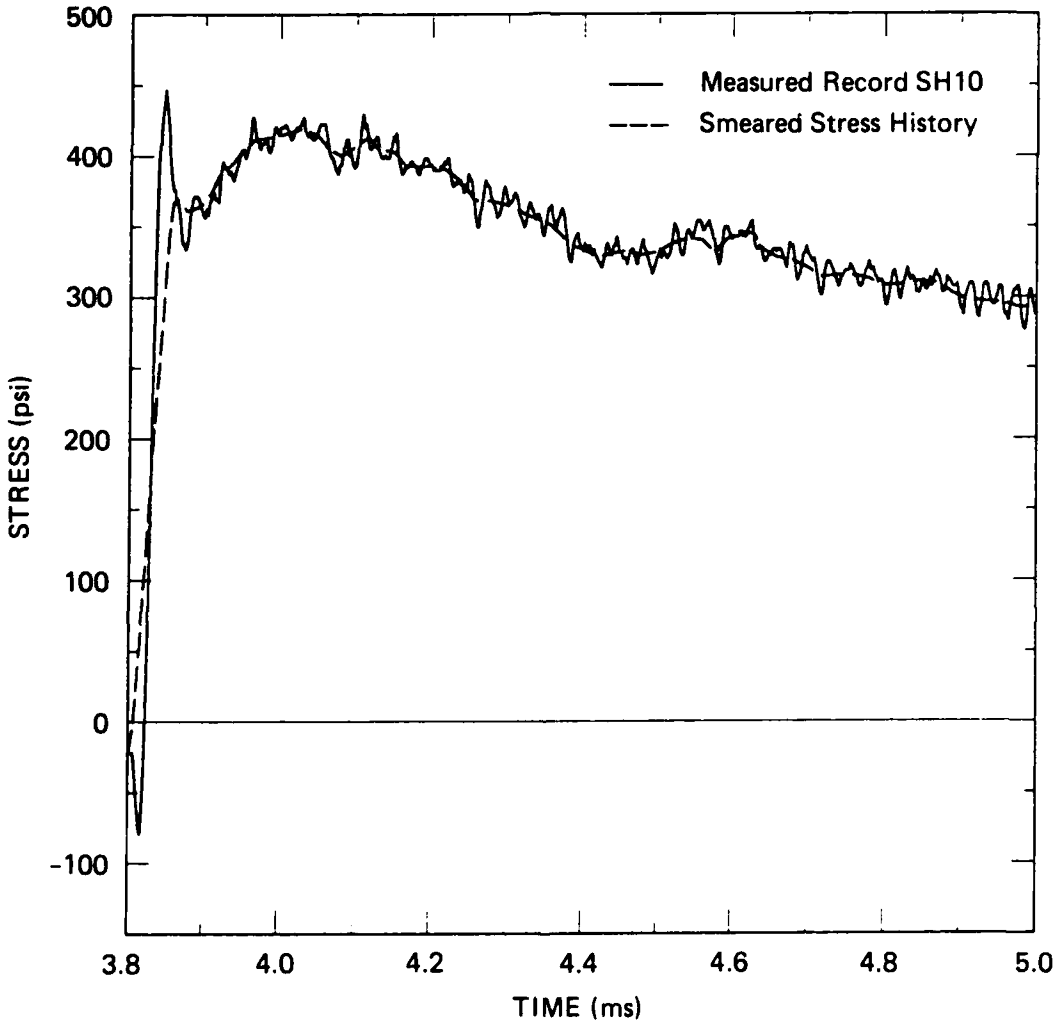
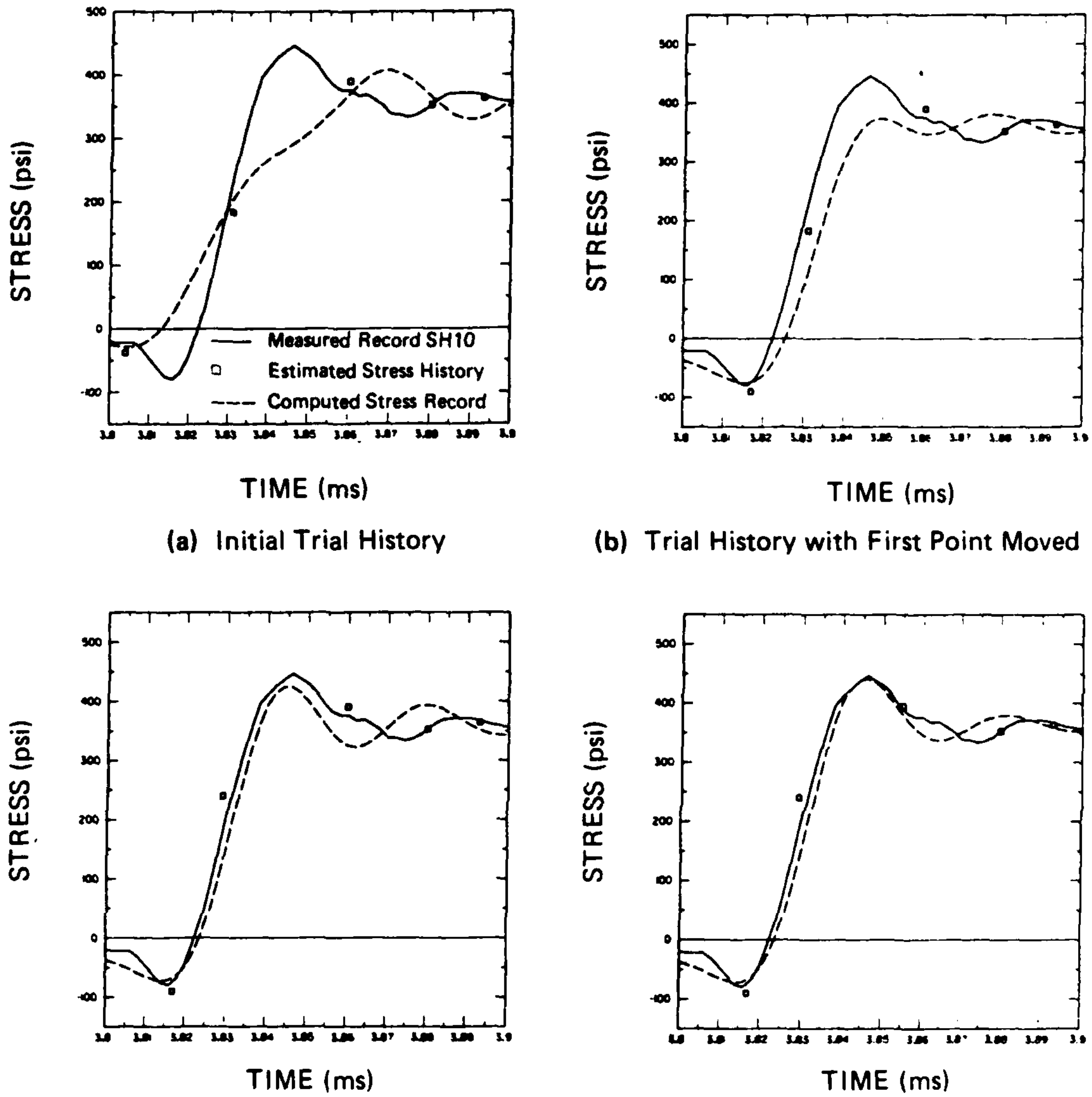


FIGURE 16 MEASURED HORIZONTAL STRESS RECORD SH10 FROM DISKO-1 PLUS SMEARED STRESS HISTORY COMPUTED FROM THE TRIAL HISTORY IN FIGURE 15



(a) Initial Trial History

(b) Trial History with First Point Moved

(c) Trial History with First and Second Points Moved

(d) Trial Stress History with First Three Points Moved

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FIGURE 17 SEQUENCE OF CHANGES TO THE TRIAL STRESS HISTORY TO PRODUCE A CLOSE MATCH BETWEEN THE MEASURED RECORD AND COMPUTED HISTORY FOR HORIZONTAL STRESS RECORD SH10 ON DISKO-1

```
-> N
   IS RECORD FINISHED?  WANT TO EXIT?
 -> N
 1st SHOCK AT T =   3.8240E-03 STRESS JUMP =   3.2065E+02
 2nd SHOCK AT T =   3.5360E-03 STRESS JUMP =   4.8650E+01
```

Notes: The shocks are selected by the program to guide the user in finding the areas of interest for his work of modifying the history. In the present case, the shock to examine is the first shock, at 3.824 ms. The shocks are selected for the steepness of their rise in time and are listed in order of amplitude, not time. The amplitudes in this example are given in psi and the times are in seconds. The times are at the beginning of the shock front, the location for the user to begin his modifications of the record.

```
   ENTER TIME INTERVAL FOR CHANGING RECORD - TBEG,TEND (SEC)
      THREE POINTS ARE USED, BEGINNING WITH TBEG
 -> 3.8E-03, 3.9E-03
```

Notes: The program uses TBEG and selects three (time, amplitude) points in the history to begin the modifications. At this point in the operation we begin the manual modification of the estimated stress history.

```
   WANT TO PLOT STRESS RECORD, ESTIMATED HISTORY, AND COMPUTED?
 -> N

   XMIN, XMAX =    3.800E-03  3.900E-03  WANT TO CHANGE THEM?
 -> N
   VARIANCE VO =   2.865E+05
```

Notes: The variance is computed from the difference between the original record and the computed history.

```
   FR. DAMP =  1.500E-01  PERIOD =  4.000E-05

   FOR TIME INTERVAL(  3.800E-03,  3.920E-03)
```

Notes: We note here that the program has chosen a slightly different window (ending at 3.92 ms. instead of 3.9 ms.) from the one we specified earlier.

I	LABEL(I)	VALUE(I)	DEL(1)	DEL(2)	VARIANCE(1)	VARIANCE(2)
1	THIST(0)	3.787E-03	1.000E-06	-1.000E-06	2.889E+05	2.991E+05
2	THIST(1)	3.804E-03	1.700E-06	-1.700E-06	2.636E+05	3.291E+05
3	THIST(2)	3.831E-03	2.700E-06	-2.700E-06	3.296E+05	2.871E+05
4	THIST(3)	3.860E-03	2.000E-06	-2.000E-06	3.098E+05	2.839E+05
5	YHIST(1)	-3.759E+01	1.000E+01	-1.000E+01	3.198E+05	2.783E+05
6	YHIST(2)	1.835E+02	2.068E+01	-2.068E+01	2.712E+05	3.368E+05
7	YHIST(3)	3.903E+02	1.000E+01	-1.000E+01	2.954E+05	3.056E+05
8	DAMP	1.500E-01	1.500E-02	-1.500E-02	2.956E+05	3.058E+05
9	TAU	4.000E-05	4.000E-06	-4.000E-06	2.624E+05	3.230E+05

Notes: THIST(i) and YHIST(i) in the preceding list are the abscissae and ordinates of the successive points defining the trial history (as in Fig. 17a). Consequently, this list shows the VALUEs of the variables that can now be changed in the trial history, the incremental changes (DEL) that have been tested, and the effects that these changes have on the VARIANCEs. We can see that an increase in THIST(1), YHIST(2), and TAU, and a decrease in YHIST(1) would offer improvements (decreases in the variance).

```
    WANT TO CHANGE THE WINDOW?
 -> N
    WANT TO CHANGE ANY VALUE OF TRIAL RECORD?
 -> Y
    TO CHANGE ANY VALUE ENTER THE "I" VALUE FOR THE VARIABLE
       0 - TO EXIT CHANGE LOOP
```

Notes: At this point we decide to change the time and amplitude of the first point (I values 2 and 5).

```
 -> 2
    ENTER NEW VALUE OF VARIABLE BEING CHANGED
 ->    3.817E-03
    I= 1   THIST(ORIGINAL)=   3.787E-03  (NEW)=   0.000E+00
    I= 2   THIST(ORIGINAL)=   3.804E-03  (NEW)=   3.817E-03
    I= 3   THIST(ORIGINAL)=   3.831E-03  (NEW)=   0.000E+00
    I= 4   THIST(ORIGINAL)=   3.860E-03  (NEW)=   0.000E+00
    I= 5   YHIST(ORIGINAL)=  -3.759E+01  (NEW)=   0.000E+00
    I= 6   YHIST(ORIGINAL)=   1.835E+02  (NEW)=   0.000E+00
    I= 7   YHIST(ORIGINAL)=   3.903E+02  (NEW)=   0.000E+00
    I= 8    DAMP(ORIGINAL)=   1.500E-01  (NEW)=   0.000E+00
    I= 9     TAU(ORIGINAL)=   4.000E-05  (NEW)=   0.000E+00
    TO CHANGE ANY VALUE ENTER THE "I" VALUE FOR THE VARIABLE
       0 - TO EXIT CHANGE LOOP
 -> 5
    ENTER NEW VALUE OF VARIABLE BEING CHANGED
 ->   -9.000E+01
    I= 1   THIST(ORIGINAL)=   3.787E-03  (NEW)=   0.000E+00
    I= 2   THIST(ORIGINAL)=   3.804E-03  (NEW)=   3.817E-03
    I= 3   THIST(ORIGINAL)=   3.831E-03  (NEW)=   0.000E+00
    I= 4   THIST(ORIGINAL)=   3.860E-03  (NEW)=   0.000E+00
    I= 5   YHIST(ORIGINAL)=  -3.759E+01  (NEW)=  -9.000E+01
    I= 6   YHIST(ORIGINAL)=   1.835E+02  (NEW)=   0.000E+00
    I= 7   YHIST(ORIGINAL)=   3.903E+02  (NEW)=   0.000E+00
    I= 8    DAMP(ORIGINAL)=   1.500E-01  (NEW)=   0.000E+00
    I= 9     TAU(ORIGINAL)=   4.000E-05  (NEW)=   0.000E+00
    TO CHANGE ANY VALUE ENTER THE "I" VALUE FOR THE VARIABLE
       0 - TO EXIT CHANGE LOOP
 -> 0


    WANT TO PLOT STRESS RECORD, ESTIMATED HISTORY, AND COMPUTED?
```

```
-> Y
```

Notes: The resulting change in the match between the original record and the computed history is evident in Figure 17b. The variance (which follows) has been significantly reduced.

```
    VARIANCE VO =   1.574E+05

    FR. DAMP =  1.500E-01  PERIOD =  4.000E-05

    FOR TIME INTERVAL(  3.800E-03,  3.920E-03)

  I  LABEL(I)     VALUE(I)     DEL(1)      DEL(2)      VARIANCE(1)
VARIANCE(2)
  1  THIST(0)    3.787E-03   1.000E-06  -1.000E-06   1.579E+05   1.570E+05
  2  THIST(1)    3.817E-03   1.400E-06  -1.400E-06   1.743E+05   1.462E+05
  3  THIST(2)    3.831E-03   1.400E-06  -1.400E-06   1.950E+05   1.261E+05
  4  THIST(3)    3.860E-03   2.000E-06  -2.000E-06   1.720E+05   1.441E+05
  5  YHIST(1)   -9.000E+01   1.000E+01  -1.000E+01   1.559E+05   1.616E+05
  6  YHIST(2)    1.835E+02   2.068E+01  -2.068E+01   1.157E+05   2.085E+05
  7  YHIST(3)    3.903E+02   1.000E+01  -1.000E+01   1.532E+05   1.641E+05
  8   DAMP       1.500E-01   1.500E-02  -1.500E-02   1.677E+05   1.483E+05
  9    TAU       4.000E-05   4.000E-06  -4.000E-06   1.814E+05   1.657E+05
    WANT TO CHANGE THE WINDOW?
 -> N
    WANT TO CHANGE ANY VALUE OF TRIAL RECORD?
 -> Y
    TO CHANGE ANY VALUE ENTER THE "I" VALUE FOR THE VARIABLE
       0 - TO EXIT CHANGE LOOP
```

Notes: Here we move the 2nd point in time and amplitude (I values of 3 and 6).

```
 -> 3
    ENTER NEW VALUE OF VARIABLE BEING CHANGED
 ->    3.829E-03
    I= 1   THIST(ORIGINAL)=   3.787E-03  (NEW)=   0.000E+00
    I= 2   THIST(ORIGINAL)=   3.804E-03  (NEW)=   3.817E-03
    I= 3   THIST(ORIGINAL)=   3.831E-03  (NEW)=   3.829E-03
    I= 4   THIST(ORIGINAL)=   3.860E-03  (NEW)=   0.000E+00
    I= 5   YHIST(ORIGINAL)=  -3.759E+01  (NEW)=  -9.000E+01
    I= 6   YHIST(ORIGINAL)=   1.835E+02  (NEW)=   0.000E+00
    I= 7   YHIST(ORIGINAL)=   3.903E+02  (NEW)=   0.000E+00
    I= 8    DAMP(ORIGINAL)=   1.500E-01  (NEW)=   0.000E+00
    I= 9     TAU(ORIGINAL)=   4.000E-05  (NEW)=   0.000E+00
    TO CHANGE ANY VALUE ENTER THE "I" VALUE FOR THE VARIABLE
       0 - TO EXIT CHANGE LOOP
```

```
-> 6
   ENTER NEW VALUE OF VARIABLE BEING CHANGED
->     2.400E+02
   I= 1   THIST(ORIGINAL)=   3.787E-03  (NEW)=   0.000E+00
   I= 2   THIST(ORIGINAL)=   3.804E-03  (NEW)=   3.817E-03
   I= 3   THIST(ORIGINAL)=   3.831E-03  (NEW)=   3.829E-03
   I= 4   THIST(ORIGINAL)=   3.860E-03  (NEW)=   0.000E+00
   I= 5   YHIST(ORIGINAL)=  -3.759E+01  (NEW)=  -9.000E+01
   I= 6   YHIST(ORIGINAL)=   1.835E+02  (NEW)=   2.400E+02
   I= 7   YHIST(ORIGINAL)=   3.903E+02  (NEW)=   0.000E+00
   I= 8    DAMP(ORIGINAL)=   1.500E-01  (NEW)=   0.000E+00
   I= 9     TAU(ORIGINAL)=   4.000E-05  (NEW)=   0.000E+00
   TO CHANGE ANY VALUE ENTER THE "I" VALUE FOR THE VARIABLE
      0 - TO EXIT CHANGE LOOP
-> 0


   WANT TO PLOT STRESS RECORD, ESTIMATED HISTORY, AND COMPUTED?
-> Y
```

Notes: The resulting plot is in Figure 17c. Again the match has been improved considerably.

```
   VARIANCE V0 =    4.889E+04

   FR. DAMP =  1.500E-01   PERIOD =  4.000E-05

   FOR TIME INTERVAL(  3.800E-03,  3.920E-03)
```

I	LABEL(I)	VALUE(I)	DEL(1)	DEL(2)	VARIANCE(1)	VARIANCE(2)
1	THIST(0)	3.787E-03	1.000E-06	-1.000E-06	4.867E+04	4.915E+04
2	THIST(1)	3.817E-03	1.200E-06	-1.200E-06	5.517E+04	4.738E+04
3	THIST(2)	3.829E-03	1.200E-06	-1.200E-06	5.661E+04	4.659E+04
4	THIST(3)	3.860E-03	2.000E-06	-2.000E-06	5.908E+04	3.984E+04
5	YHIST(1)	-9.000E+01	1.000E+01	-1.000E+01	4.597E+04	5.432E+04
6	YHIST(2)	2.400E+02	1.503E+01	-1.503E+01	4.260E+04	5.995E+04
7	YHIST(3)	3.903E+02	1.000E+01	-1.000E+01	4.425E+04	5.585E+04
8	DAMP	1.500E-01	1.500E-02	-1.500E-02	4.758E+04	5.299E+04
9	TAU	4.000E-05	4.000E-06	-4.000E-06	4.915E+04	7.909E+04

```
   WANT TO CHANGE THE WINDOW?
-> N
   WANT TO CHANGE ANY VALUE OF TRIAL RECORD?
-> Y
   TO CHANGE ANY VALUE ENTER THE "I" VALUE FOR THE VARIABLE
      0 - TO EXIT CHANGE LOOP
```

Notes: At this time we moved the third point in time and amplitude (I values of 4 and 7).

```
-> 4
   ENTER NEW VALUE OF VARIABLE BEING CHANGED
```

```
->    3.855E-03
   I= 1   THIST(ORIGINAL)=   3.787E-03  (NEW)=   0.000E+00
   I= 2   THIST(ORIGINAL)=   3.804E-03  (NEW)=   3.817E-03
   I= 3   THIST(ORIGINAL)=   3.831E-03  (NEW)=   3.829E-03
   I= 4   THIST(ORIGINAL)=   3.860E-03  (NEW)=   3.855E-03
   I= 5   YHIST(ORIGINAL)=  -3.759E+01  (NEW)=  -9.000E+01
   I= 6   YHIST(ORIGINAL)=   1.835E+02  (NEW)=   2.400E+02
   I= 7   YHIST(ORIGINAL)=   3.903E+02  (NEW)=   0.000E+00
   I= 8    DAMP(ORIGINAL)=   1.500E-01  (NEW)=   0.000E+00
   I= 9     TAU(ORIGINAL)=   4.000E-05  (NEW)=   0.000E+00
   TO CHANGE ANY VALUE ENTER THE "I" VALUE FOR THE VARIABLE
      0 - TO EXIT CHANGE LOOP
-> 7
   ENTER NEW VALUE OF VARIABLE BEING CHANGED
->    3.950E+02
   I= 1   THIST(ORIGINAL)=   3.787E-03  (NEW)=   0.000E+00
   I= 2   THIST(ORIGINAL)=   3.804E-03  (NEW)=   3.817E-03
   I= 3   THIST(ORIGINAL)=   3.831E-03  (NEW)=   3.829E-03
   I= 4   THIST(ORIGINAL)=   3.860E-03  (NEW)=   3.855E-03
   I= 5   YHIST(ORIGINAL)=  -3.759E+01  (NEW)=  -9.000E+01
   I= 6   YHIST(ORIGINAL)=   1.835E+02  (NEW)=   2.400E+02
   I= 7   YHIST(ORIGINAL)=   3.903E+02  (NEW)=   3.950E+02
   I= 8    DAMP(ORIGINAL)=   1.500E-01  (NEW)=   0.000E+00
   I= 9     TAU(ORIGINAL)=   4.000E-05  (NEW)=   0.000E+00
   TO CHANGE ANY VALUE ENTER THE "I" VALUE FOR THE VARIABLE
      0 - TO EXIT CHANGE LOOP
-> 0
```

Notes: We are now happy with the correspondence between the original record and the computed history, so we end the session.

```
   WANT TO PLOT STRESS RECORD, ESTIMATED HISTORY, AND COMPUTED?
-> Y
```

Notes: The figure plotted at this time is shown in Figure 17d.

```
   VARIANCE V0 =   2.768E+04

   FR. DAMP =  1.500E-01   PERIOD =  4.000E-05

   FOR TIME INTERVAL(  3.800E-03,  3.920E-03)
```

I	LABEL(I)	VALUE(I)	DEL(1)	DEL(2)	VARIANCE(1)	VARIANCE(2)
1	THIST(0)	3.787E-03	1.000E-06	-1.000E-06	2.763E+04	2.774E+04
2	THIST(1)	3.817E-03	1.200E-06	-1.200E-06	3.706E+04	2.340E+04
3	THIST(2)	3.829E-03	1.200E-06	-1.200E-06	3.708E+04	2.364E+04
4	THIST(3)	3.855E-03	2.500E-06	-2.500E-06	3.561E+04	2.343E+04
5	YHIST(1)	-9.000E+01	1.000E+01	-1.000E+01	2.467E+04	3.316E+04
6	YHIST(2)	2.400E+02	1.550E+01	-1.550E+01	2.453E+04	3.562E+04

```
  7  YHIST(3)     3.950E+02   1.000E+01  -1.000E+01    2.515E+04    3.250E+04
  8   DAMP        1.500E-01   1.500E-02  -1.500E-02    2.822E+04    2.932E+04
  9    TAU        4.000E-05   4.000E-06  -4.000E-06    4.858E+04    4.414E+04
    WANT TO CHANGE THE WINDOW?
 -> N
    WANT TO CHANGE ANY VALUE OF TRIAL RECORD?
 -> N

    WANT TO PLOT STRESS RECORD, ESTIMATED HISTORY, AND COMPUTED?
     -N-  SENDS TO END
 -> Y

    XMIN, XMAX =    3.800E-03  3.900E-03  WANT TO CHANGE THEM?
 -> Y

    ENTER XMIN,XMAX
 ->    3.800E-03   5.000E-03
```

Notes: Here a plot like that in Figure 18 is generated. The solid line is the original record, the symbols are the trial stress history, and the dashed line is the computed stress history.

```
    WANT TO GO BACK TO MODIFY RECORD FURTHER?
       -N- SEND TO END
 -> N
    WANT HARD COPIES OF RESULTS?
 -> Y
   ***   PLOTTING ACTUAL, EST., COMPUTED RECORDS

    XMIN, XMAX =    3.800E-03  5.000E-03  WANT TO CHANGE THEM?
 -> N
```

Notes: This figure is not shown.

```
   ***   PLOTTING ACTUAL, SMEARED, AND COMPUTED RECORDS

    XMIN, XMAX =    3.800E-03  5.000E-03  WANT TO CHANGE THEM?
 -> N
```

Notes: This figure is not shown.

```
   ***   PLOTTING FINAL RECORD

    XMIN, XMAX =    3.800E-03  5.000E-03  WANT TO CHANGE THEM?
 -> N
```

Notes: The result is Figure 19.

```
    DO YOU WANT TO CALCULATE VELOCITY?
 -> N
```

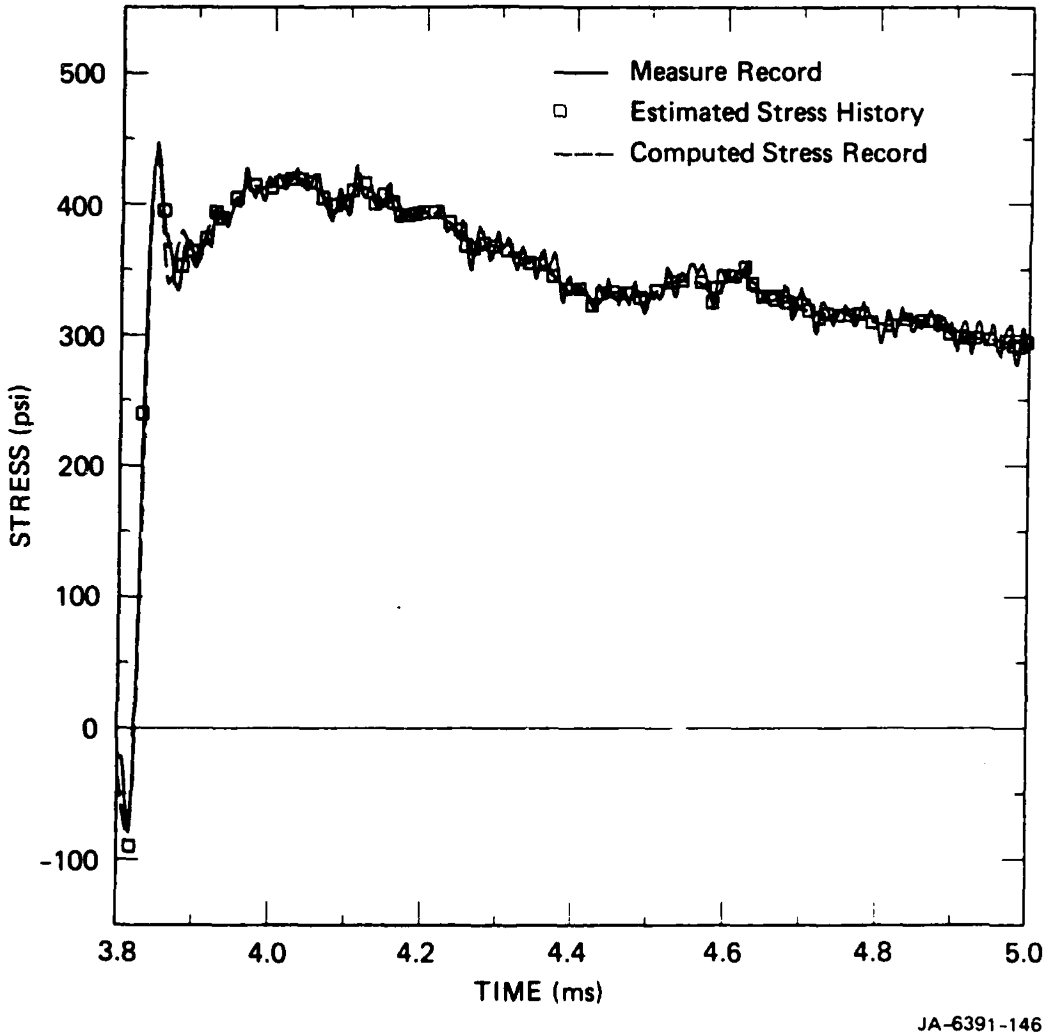


FIGURE 18 COMPARISON OF MEASURED RECORD, ESTIMATED STRESS HISTORY AND COMPUTED STRESS RECORD FOR SH10 ON DISKO-1

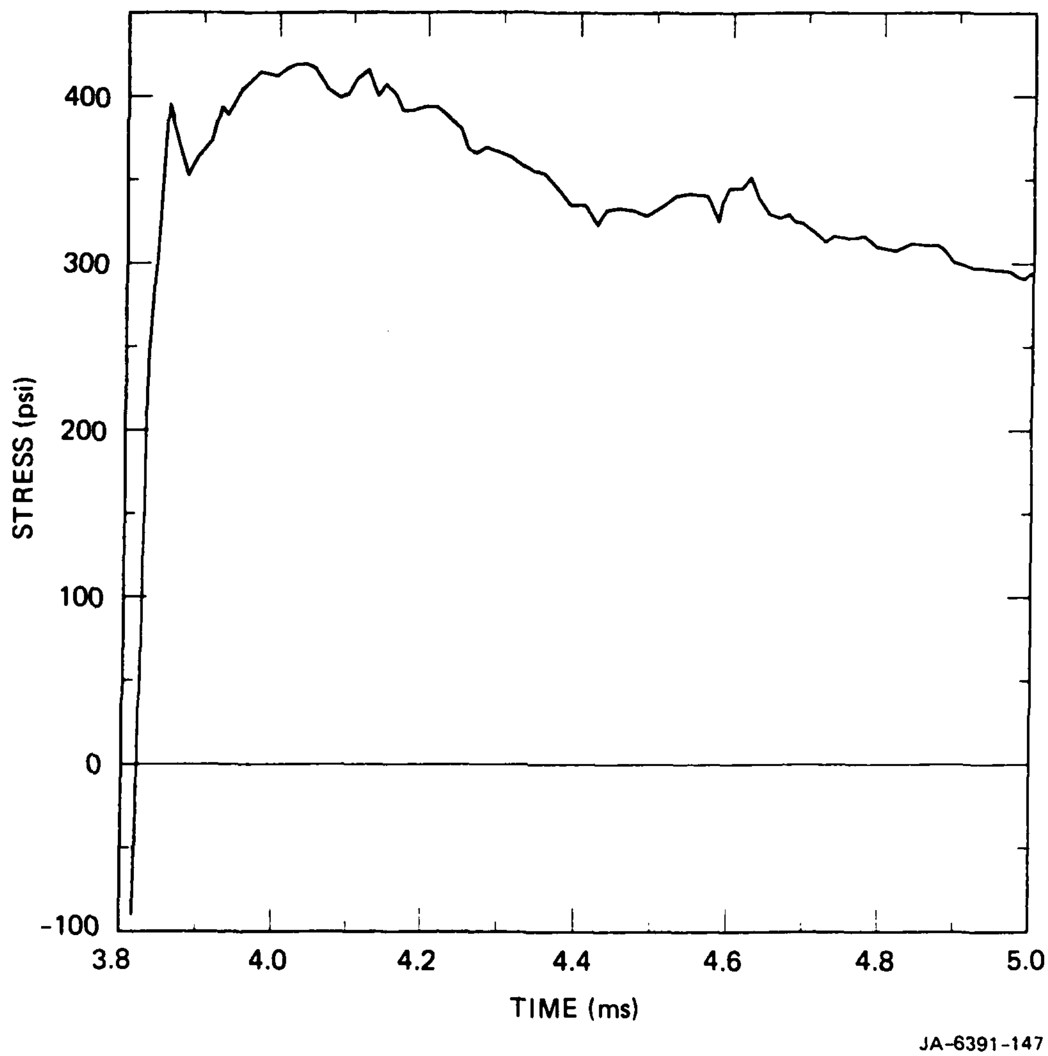


FIGURE 19 FINAL ESTIMATED STRESS HISTORY DERIVED FROM RECFIT FOR HORIZONTAL STRESS RECORD SH10 ON DISKO-1

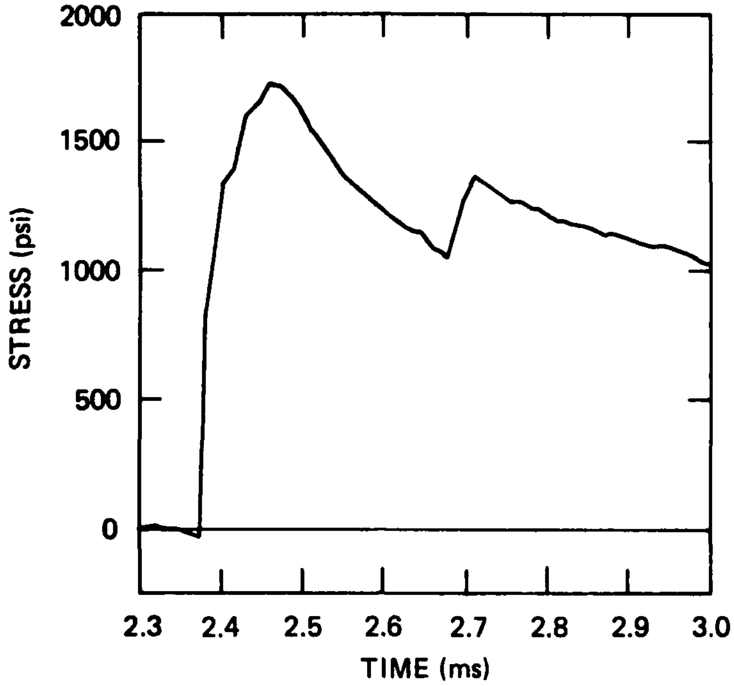
V SAMPLE RESULTS FROM THE RECFIT PROCEDURE

All the vertical and horizontal SE stress gage records from DISKO-1 were processed with RECFIT. Samples of these results are presented here.

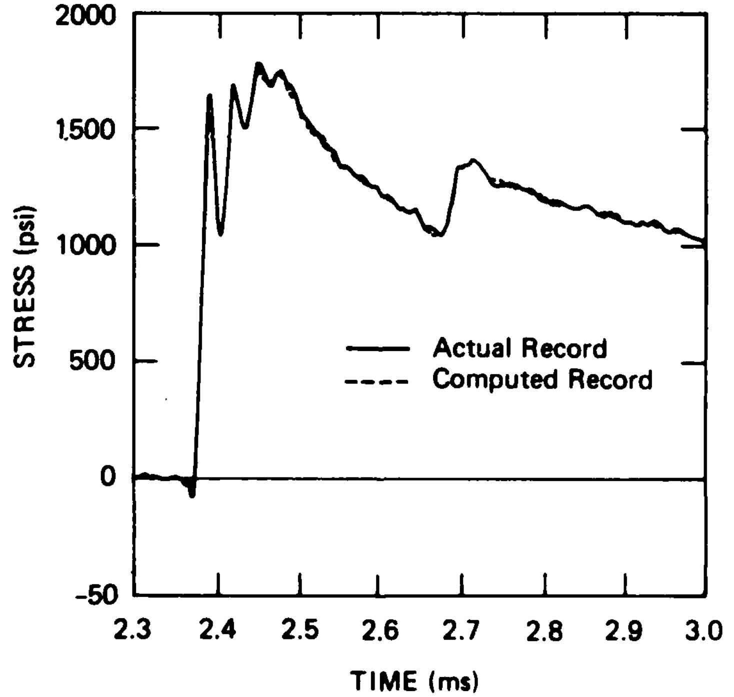
Figures 20 and 21 show the records and stress histories for vertical stress gages SV1 and SV15. The constructed histories [20(a) and 21(a)] show a rapid rise to midheight of the first shock front and a more gradual rise thereafter. This is the kind of shock front detail we had hoped to obtain with the procedure. (For this study the shock front is considered to be a portion of the record in which there is a large increase in stress in 20 to 50 μs.) Figures 20(b) and 21(b) compare the actual record and the pseudo record computed from the stress history in part (a) of each figure. The correspondence is very close in the area of the two shock fronts, the regions of particular importance for determining material properties.

The vertical stress records show a two-part rise in their wave fronts. For example, gage SV1 shows a steep rise to about 700 psi within 3 to 10 microseconds. The second step up to the first peak occurs more gradually over 40 to 100 microseconds.

Results for two horizontal stress gages are shown in Figures 22 and 23. The constructed histories have a similar appearance to those of the vertical gages, as they should. Because of the additional erosion of the sweeping wave effect, these wave fronts are not so clearly defined as those for the vertical stress gages. In Figures 22(b) and 23(b) the computed and actual records nearly coincide during the first few major oscillations; thereafter the actual record continues to oscillate, but the computed record is smooth. We did not continue the RECFIT process past 100 μs after the wave front to obtain a more precise match because the subsequent oscillations do not affect the stress-strain or K_o relations that can be deduced from these records.



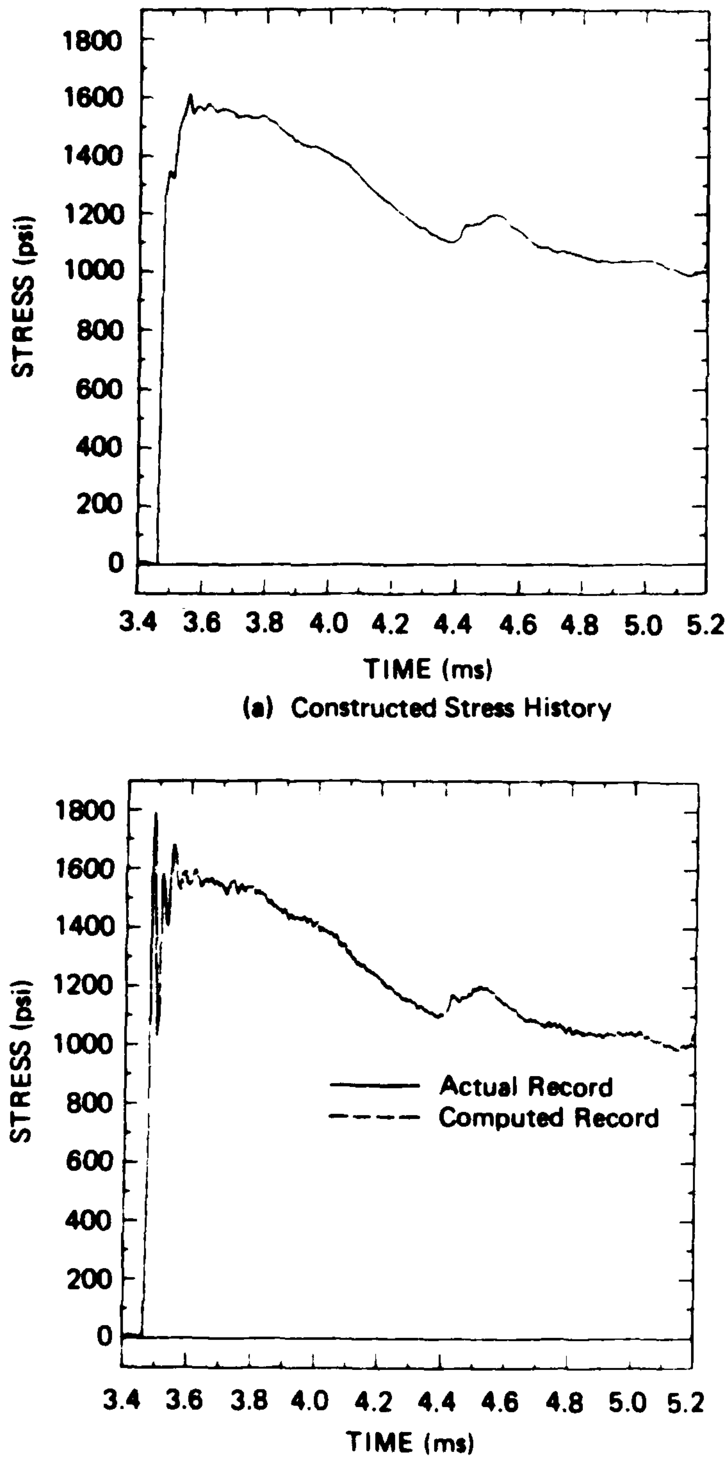
(a) Constructed Stress History



(b) Actual and Computed Stress Records

JA-6391-27A

FIGURE 20 CONSTRUCTED STRESS HISTORY AND STRESS RECORDS FROM SE GAGE SV1 IN THE DISKO-1 EXPERIMENT

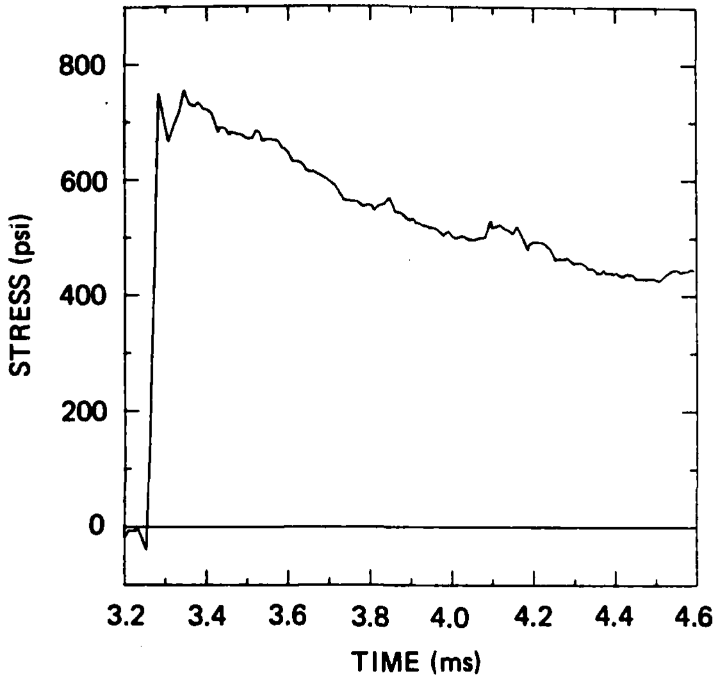


(a) Constructed Stress History

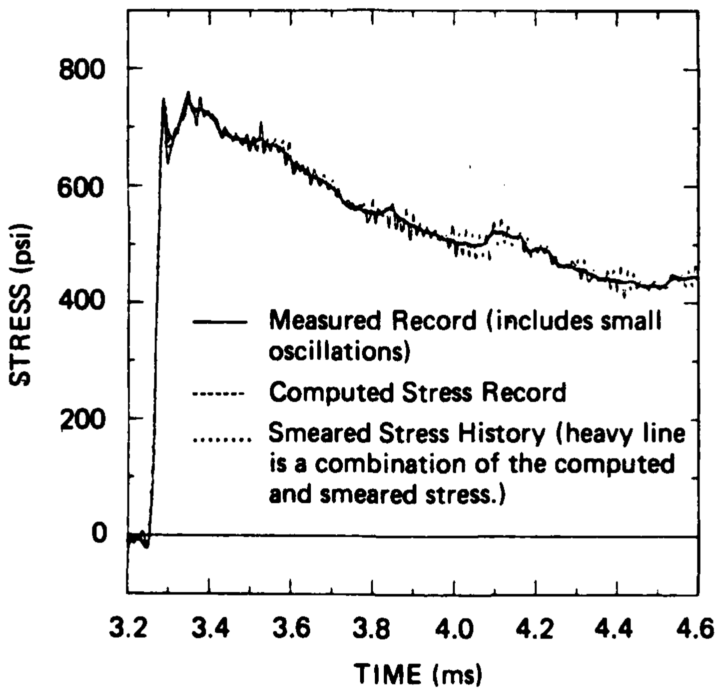
(b) Actual and Computed Stress Records

JA-6391-28A

FIGURE 21 CONSTRUCTED STRESS HISTORY AND STRESS RECORDS FROM SE GAGE SV15 IN THE DISKO-1 EXPERIMENT



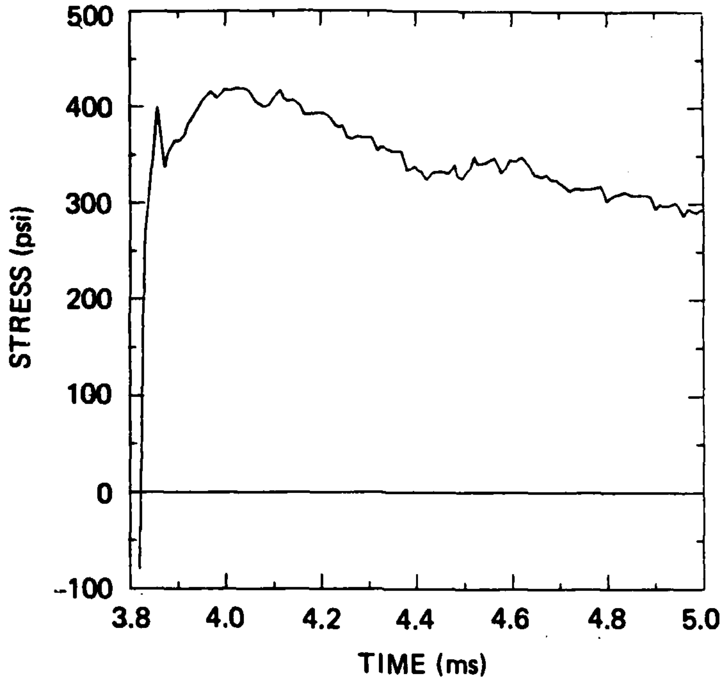
(a) Constructed Stress History



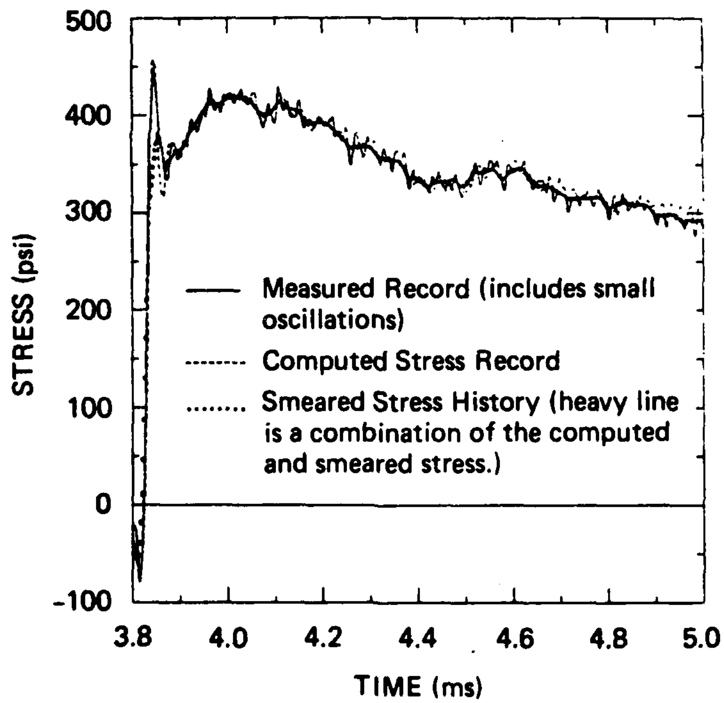
(b) Comparison of Computed and Actual Records

JA-6391-29A

FIGURE 22 CONSTRUCTED STRESS HISTORY AND STRESS RECORDS FROM SE GAGE SH8 IN THE DISKO-1 EXPERIMENT



(a) Constructed Stress History



(b) *Comparison of Computed and Actual Records*

JA-6391-30A

FIGURE 23 CONSTRUCTED STRESS HISTORY AND STRESS RECORDS FROM SE GAGE SH10 IN THE DISKO-1 EXPERIMENT

Figures 20 through 23 indicate that the RECFIT procedure produces satisfactory results for both horizontal and vertical stress gage records from the DISKO-1 event.

REFERENCES

1. Windham, J. E. January 1982. "Test Plan for Dynamic In Situ K_o Tests (DISKO-1)," US Army Engineer Waterways Experiment Station, Vicksburg, MS.

2. Windham, J. E. September 1986. "In Situ Backfill Property Test Program: Report 1, Results from DISKO-1 on Dry Flume Sand," Technical Report SL-86-21, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

3. Seaman, L. July 1987. "Analysis of Dynamic In Situ Backfill Property Tests: Report 2, An Improved Lagrangian Analysis for Stress and Particle Velocity Gage Arrays," Technical Report SL-87-11, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

4. Radhakrishnan, N., and B. Rohani. November 1971. "A One-Dimensional Plane Wave Propagation Code for Layered Nonlinear Hysteretic Media," Technical Report S-71-12, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

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6. Timoshenko, S., and Woinowsky-Krieger, S. 1959. Theory of Plates and Shells, 2nd ed, McGraw-Hill Publishing Co., New York, NY.

7. Biggs, J. M. 1964. Introduction to Structural Dynamics, McGraw-Hill Publishing Co., New York, NY.

Appendix A

CONSTRUCTION OF A GAGE RECORD FOR A PRESCRIBED VERTICAL STRESS HISTORY

At several points in the study, it was necessary to construct a gage record for a prescribed stress history, while accounting for the gage frequency and damping. Both an analytical and a numerical procedure were developed for the record construction. For the exploratory studies, the analytical approach was used in a small program called MAKREC. For the main program RECFIT, the numerical method was used. Both procedures are outlined here.

The basic equation governing the gage response describes the displacement y of a damped, one-degree-of-freedom oscillator[7]:

$$\ddot{y} + 2\beta\dot{y} + \omega^2 y = \omega^2 y_{ST} f(t) \tag{A.1}$$

where y_{ST} is the peak static response that would occur under the prescribed loading and f(t) is the loading history. The circular frequency of the oscillator and gage is ω, and β is the damping factor defined such that β/ω is the fraction of critical damping.

We consider only displacements y and y_{ST} and no stresses because of the nature of the SE stress gage. The gage is calibrated so that its strain (or equivalently deflection) is related to a surface stress. Thus, through the calibration factor we can relate y_{ST} to the prescribed loading and y to the apparent stress recorded by the gage.

For the analytical solution, we start with the integral form of equation (A.1), as given by Biggs:[7]

$$y = y_{ST} \frac{\omega^2}{\omega_d} \int_{t_1}^{t} f(\tau)\, e^{-\beta(t-\tau)} \sin \omega_d(t - \tau)\, d\tau \tag{A.2}$$

$$+ e^{-\beta t} \frac{\dot{y}_o + \beta y_o}{\omega_d} \sin \omega_d t + y_o \cos \omega_d t$$

Here ω_d is the damped circular frequency:

$$\omega_d^2 = \omega^2 - \beta^2 \tag{A.3}$$

and y_o and $\dot{y}_o$ are the position and velocity at $t = t_i$. The loading consists of a series of linear segments starting at the origin, as shown in Figure A.1. The analysis is then derived for the response of the oscillator to a single ramp loading given by

$$y_{ST} f(\tau) = \frac{\Delta y}{\Delta t} (\tau - t_i) \tag{A.4}$$

where t_i is the starting time for the ramp. The response to the series of linear segments is then obtained by superposition. The angles for the successive ramps are shown in Figure A.1. For a ramp loading extending from t_i to some time t, equation (A.2) can be integrated to give:

$$y = \frac{\Delta y}{\Delta t} \left\{ t - t_i - \frac{2\beta}{\omega^2} - \frac{e^{-\beta(t - t_i)}}{\omega_d} \left[\left(1 - \frac{2\beta^2}{\omega^2}\right) \sin \omega_d (t - t_i) - \frac{2\beta\omega_d}{\omega^2} \cos \omega_d (t - t_i) \right] \right\} \tag{A.5}$$

where $\Delta y/\Delta t$ is the rate of rise of the ramp loading.

When we designate the contribution of the i^{th} ramp loading as y_i, then the displacement (or apparent stress on the gage) is

$$y = \sum_{i=1}^{I} y_i \tag{A.6}$$

where I is the number of linear segments used to construct the loading at the current time t.

The foregoing analysis was used in the MAKREC program. This analysis would be time-consuming and inconvenient for a calculation with many prescribed loading points, so a numerical method was used for the RECFIT program.

A numerical integration of the equation of motion was constructed for RECFIT in the subroutine RUNG. RUNG uses a fourth-order Runge-Kutta technique for each time interval of the digitized stress records. The basic equation of the damped oscillator, equation (A.1), is rewritten as two first degree equations in velocity u and position y:

$$\dot{u} + 2\beta u + \omega^2 y = \omega^2 y_{ST} f(t) \qquad \text{(A.7a)}$$

$$\dot{y} = u \qquad \text{(A.7b)}$$

This pair of equations is then integrated by the Runge-Kutta procedure to determine values of y at each time step.

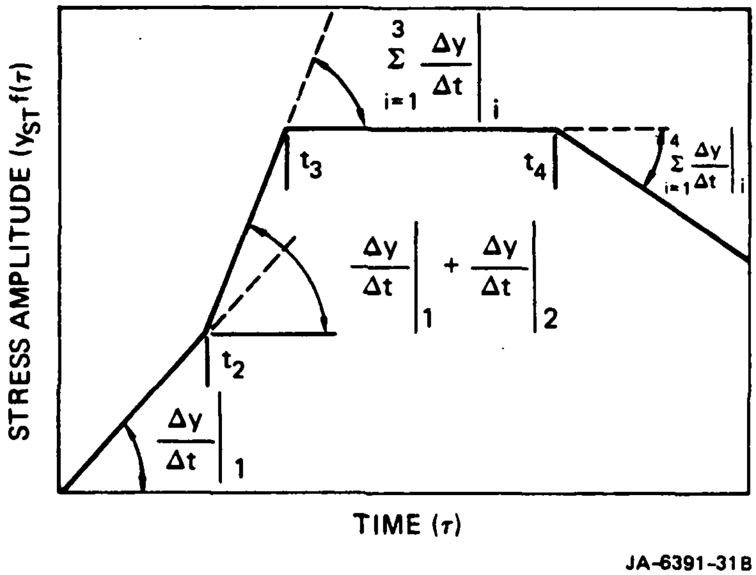


FIGURE A.1 DESCRIPTION OF A PRESCRIBED LOADING COMPOSED OF LINEAR SEGMENTS

Appendix B

ACCOUNTING FOR A STRESS WAVE THAT SWEEPS OVER A DIAPHRAGM GAGE FACE

A stress wave that gradually sweeps over a diaphragm stress gage produces a stress record with a gradual rise to it. The shape of this gradually rising record is derived here. Then a method is developed for accounting for this sweeping effect for waves of arbitrary history.

To analyze this gradual loading, we considered first the response of a clamped circular elastic plate to a step wave that sweeps over the plate. The expression for the central deflection dw for a stress $\bar{p}$ acting on an area dA at a radius b is (from Timoshenko[6])

$$dw = \frac{\bar{p}}{8\pi D}\left(b^2 \ln\frac{b}{a} + \frac{a^2 - b^2}{2}\right) dA \tag{B.1}$$

where a and D are the radius and the bending stiffness of the plate, respectively. The geometry of the wave and plate dimensions are shown in Figure B.1.

The central deflection under a step wave sweeping across the gage from $-a$ to b is obtained by integrating equation (B.1).

$$\frac{w}{w_m} = \frac{8}{\pi}\int_{-a}^{b}\int_{-H}^{H}\left[\frac{b^2}{a^2}\ln\frac{b}{a} + \frac{1}{2}\left(1 - \frac{b^2}{a^2}\right)\right]\frac{dh\,dx}{a^2} \tag{B.2}$$

where H and $-H$ are the limits on the vertical strip of load shown in Figure B.1 and w_m is the central deflection under a uniform load q applied to the entire plate:

$$w_m = \frac{qa^4}{64D} \tag{B.3}$$

For evaluating equation (B.2), b is written as

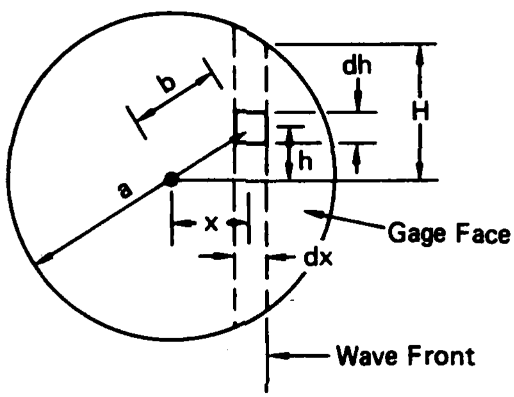


FIGURE B.1 NOMENCLATURE FOR ANALYSIS OF THE RESPONSE OF THE SE DIAPHRAGM GAGE TO A SWEEPING WAVE

$$b^2 = h^2 + x^2 \tag{B.4}$$

where h is the vertical distance to the loaded point as shown in Figure B.1.

Equation (B.2) was integrated numerically to study the response to the sweeping wave. The central deflection for the step pulse is shown in Figure B.2. Evidently, the gage responds very little when the wave first reaches the gage, so the response is not proportional to the crossing time (nor to the gage area covered). To further aid in understanding the response, the analysis was repeated for a loading only along a vertical strip, as shown in Figure B.3. Here the differential quantity $(\Delta w/\Delta x)/w_m$ is plotted. This differential quantity is the one to be used later for computing records for stress histories of arbitrary shape.

For routine use of the response function in Figure B.3, it was expedient to find a simple analytical approximation. We chose

$$\begin{aligned} y &= Y \sin^2 \pi \left(c \frac{t - \bar{t}}{2a/Y} + \frac{1}{2}\right) \\ &\text{for } t = \bar{t} - \frac{a}{Yc} \text{ to } \bar{t} + \frac{a}{Yc} \end{aligned} \tag{B.5}$$

where $\bar{t}$ is the time at the center of the gage $Y = 1.13$ is the amplitude at the center, and c is the sound speed. In this approximation, the gage response begins at the starred point at the left in Figure B.3, rises to the correct peak, and returns to zero at the starred point on the right. The coefficients in equation (B.5) were selected so that the integral over the approximate response function agrees with the exact result.

For a time increment from t_{i-1} to t_i, equation (B.5) can be integrated to obtain the appropriate response function:

$$\Delta F_i = \frac{1}{\Delta t} \int_{t_{i-1}}^{t_i} F dt = \left[\frac{ct}{2a/Y} - \frac{1}{2\pi} \sin 2\pi \left(c \frac{t - \bar{t}}{2a/Y} + \frac{1}{2}\right)\right]_{t_{i-1}}^{t_i} \tag{B.6}$$

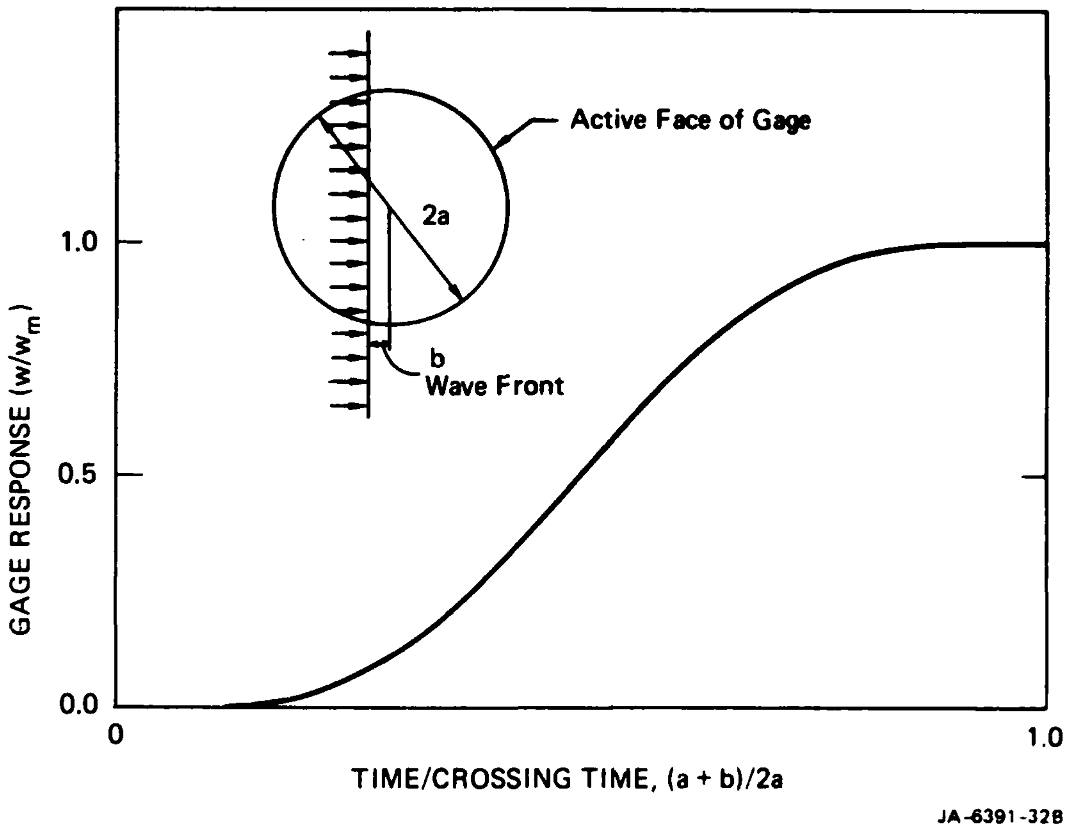


FIGURE B.2 RESPONSE OF A HORIZONTAL STRESS GAGE TO A SWEEPING STEP PULSE

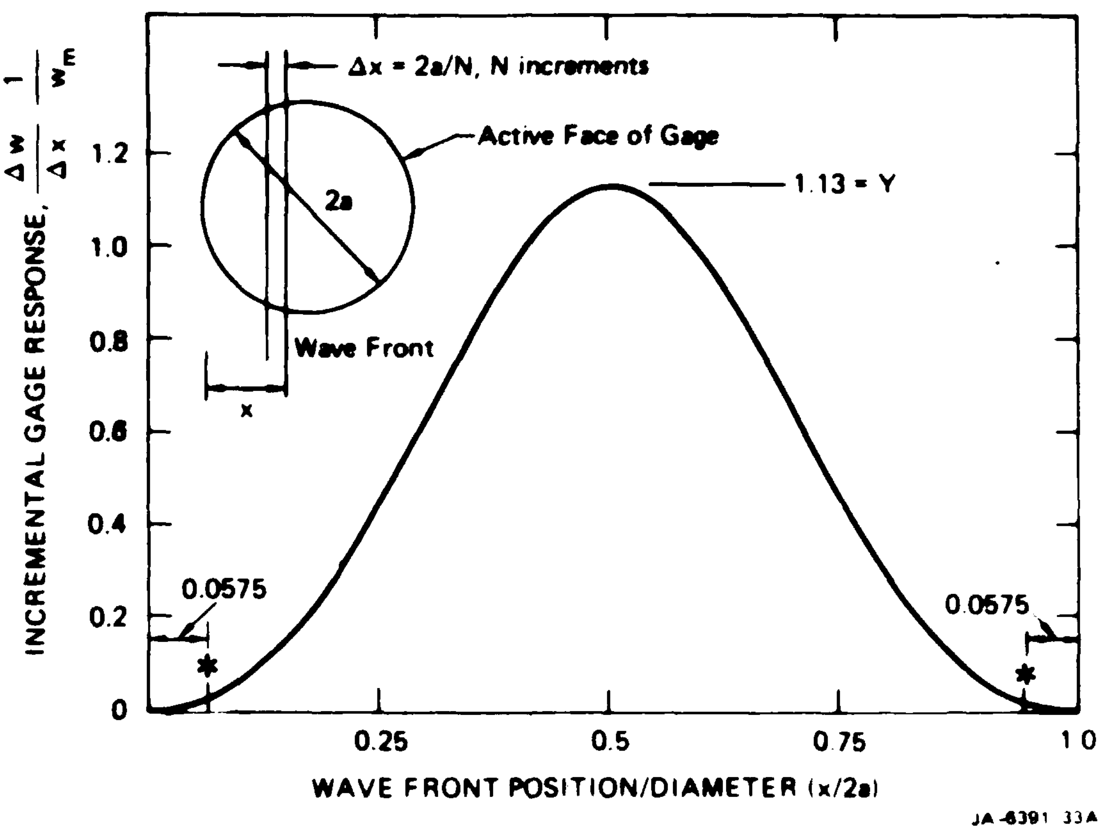


FIGURE B.3 RESPONSE OF THE HORIZONTAL STRESS GAGE TO AN INCREMENT OF THE WAVE

This expression for the response function is used in RECFIT for processing horizontal stress gage records.

Appendix C

LISTING OF RECFIT

The following listing contains all the subroutines used with RECFIT, listed in alphabetical order after the main program. Included are FNDSHK, HORGAGE, MINMAX, REC1ST, RECOPT, RECPLT, RUNG, RECRED, and VARIAN. The purpose of each subroutine is listed below.

FINDSHK: Locate the region of shock fronts (rapidly changing stresses) in the record.

HORGAGE: Provide the calculation that represents smearing the stress history over the diameter of the gage.

MINMAX: Compute the minimum and maximum of the stress in a range of times.

REC1ST: Construct the first trial stress history.

RECOPT: Determine the effect of varying some of the coordinate times and amplitudes, frequency and damping of the gage.

RECPLT: Plot graphs of the stress record and histories.

RUNG: Runge-Kutta integration of the one-degree-of-freedom equation of motion for the gage response to the trial stress history.

RECRED: Read the gage record.

VARIAN: Determine the variance between the actual record and a computed record.

The standard graphing routine GRAPH4 (and its associated routines GINITL, GPLOT, and JFRAME) is called by RECFIT and RECPLT. GRAPH4 is not provided because it has been implemented only on the SRI computers.

The main program RECFIT calls FNDSHK, HORGAGE, RECOPT, RECPLT, RECRED, REC1ST, AND RUNG. RECOPT calls HORGAGE, RUNG, and VARIAN. RECPLT calls only MINMAX. The other subroutines have no call statements to other subroutines listed here.

```
      PROGRAM RECFIT
C
C        PROGRAM FOR PROCESSING RECORDS FROM GAGES TO ELIMINATE
C        THE FREQUENCY AND DAMPING CHARACTERISTICS OF THE GAGES.
C        FOR GAGES IN WHICH THE WAVE SWEEPS OVER THE GAGE FACE, THE
C        PROGRAM CAN ALSO REMOVE THE SWEEPING EFFECT.
C
C           WRITTEN BY BONNIE LEW OF SRI IN MARCH, 1984  FOR W. E. S.
C
C        TACTL      TIME OF THE ORIGINAL RECORD, AT UNIFORM INCREMENTS
C                      OF -DT-
C        YACTL      ORIGINAL RECORD
C        YHORGG     RECORD BASED ON SMEARING A TRIAL STRESS HISTORY OVER
C                      A HORIZONTAL GAGE
C        YHIST      ESTIMATED STRESS HISTORY
C        THIST      TIME OF ESTIMATED STRESS HISTORY, NON UNIFORM -DT-
C        YRCOMP     RECORD COMPUTED BY APPLYING THE ESTIMATED STRESS
C                      HISTORY TO THE GAGE
C        YVELOC     VELOCITY COMPUTED FROM ACCELERATION
C        YACTL, YRCOMP, AND YHORGG ARE ALL AT THE TIMES GIVEN BY TACTL
C
C           MODIFIED FEB, 1986 BY FJL
C
C         FILE NUMBERS USED:
C          1  -  INPUT CONTAINING ORIGINAL RECORD
C          3  -  RESTART FILE
C          4  -  OUTPUT CONTAINING RECFIT DATA
C          5  -  INPUT FROM TERMINAL
C          6  -  OUTPUT TO SCREEN
C          8  -  RECORD OF INTERACTIVE SESSION
C          9  -  SCRATCH FILE CONTAINING SMEARING FUNCTION FROM HORGAGE
C
      IMPLICIT REAL*4 (A-H,O-Z)
      CHARACTER IDENT*50,IDAT*10
      CHARACTER*80 TITLE(3)
      CHARACTER*20 FILENAME,FILENAME3,FILENAME4,NAME,FILENAME7
      CHARACTER*9 LABEL(9),STATUS
      CHARACTER*1 IANS,IANSH,IANSA
      DIMENSION TACTL(5001),YACTL(5001),YHORGG(5001),YRCOMP(5001)
      DIMENSION  THIST(2001),YHIST(2001),YVELOC(2001)
      DIMENSION ISHOCK(2),DELTS(2),VA0(9),VA(9),DEL(9),V(9)
      DATA LABEL/' THIST(0)',' THIST(1)',' THIST(2)',' THIST(3)',
     @ ' YHIST(1)',' YHIST(2)',' YHIST(3)','  DAMP','   TAU'/
      DATA PI/3.14159265/
      OPEN (8,FILE = 'INTERACT.IVE', STATUS = 'NEW')
      OPEN (9,STATUS = 'SCRATCH')
      CALL GINITL(0)
      CALL DATE(IDAT)
      STATUS = 'NEW'
      WRITE (8,1000)
      WRITE (6,1000)
1000  FORMAT(/'     *****  RECFIT, AN INTERACTIVE RECORD FITTING'
     @    ,' PROGRAM')
C
      IBUG = 0
      XMIN = 0.
      XMAX = 0.
      LS = 0
C ***********                                                *******
C        GET FILENAME AND SET UP OUTPUT FILENAMES
```

PROGRAM RECFIT

```
C ***********                                                  *******
   20 WRITE (6,9015)
      WRITE (8,9015)
 9015 FORMAT(//'     ENTER FILE NAME CONTAINING ORIGNAL GAGE DATA')
      READ (5,9020,ERR=20) FILENAME
      WRITE (8,9019) FILENAME
9019  FORMAT (' ->',1X,A20)
 9020 FORMAT(A40)
      K=INDEX(FILENAME,'.')-1
      NAME=FILENAME(1:K)
      FILENAME3=NAME(1:K)//'.'//'RST'
      FILENAME4=NAME(1:K)//'.'//'GUI'
      OPEN (4,FILE=FILENAME4,STATUS='NEW')
C ***********                                                  *******
C        CHECK FOR RESTART RUN
C ***********                                                  *******
      WRITE (8,1111)
      WRITE (6,1111)
1111  FORMAT(/'     IS THIS A RESTART RUN?   ')
      READ (5,1002) IANS
      WRITE (8,4002) IANS
4002  FORMAT (' ->',1X,A1)
      IF (IANS .NE. 'N') STATUS = 'OLD'
      OPEN (3,FILE=FILENAME3,STATUS=STATUS,ERR=9999)
      IF (IANS .EQ. 'N') GO TO 125
C ***********                                                  *******
C          READ IN RESTART FILE FROM  XXXX.RST (FILENAME3)
C ***********                                                  *******
      READ (3,1008) IDUM
      READ (3,1021) NHIST,FD,TAU,TW,IANSH,RADIUS,SSP
      READ (3,1019) (THIST(I),YHIST(I),I=1,NHIST)
C ***********                                                  *******
C        CALL -RECRED- TO READ THE FILE CONTAINING THE GAGE RECORD
C ***********                                                  *******
125   CALL RECRED (LS,IDENT,IDAT,NPT,DT,YACTL,TACTL,FILENAME)
      IF (LS .EQ. 10) GO TO 950
      IF (IANS .EQ. 'Y') GO TO 140
C ***********                                                  *******
C        BEGIN CALCULATIONS TO CONSTRUCT A NEW STRESS HISTORY
C **********                                                   *******
135   WRITE (6,1135)
      WRITE (8,1135)
1135  FORMAT(/'     ENTER PERIOD OF THE GAGE (SEC) AND FRACTION OF',
     @    ' DAMPING',/,5X,'EXAMPLE:  2.5E-5,0.05')
      READ (5,*) TAU,FD
      WRITE (8,4135) TAU,FD
4135  FORMAT (' ->',1X,1PE7.1,',',OPF4.1)
C **********                                                   *******
C        HORIZONTAL GAGE
C **********                                                   *******
      WRITE (6,1138)
      WRITE (8,1138)
1138  FORMAT(/'     ARE THE DATA FROM A HORIZONTAL GAGE?   ')
      READ (5,1002) IANSH
      WRITE (8,4002) IANSH
C **********                                                   *******
140   TWINDO = 0.5*TAU
      VA0(8)=FD
      VA0(9)=TAU
      IF (IANS .EQ. 'Y') GO TO 150
```

PROGRAM RECFIT (Continued)

```
C *********                                                    *******
C       CALL REC1ST TO CONSTRUCT THE FIRST ESTIMATED STRESS HISTORY
C *********
      LS = 0
      CALL REC1ST (LS,NPT,DT,TWINDO,TACTL,YACTL,NHIST,THIST,YHIST)
      IF (LS .EQ. 10) GO TO 950
C *********                                                    *******
C       ENTRY POINT FOR RESTART RUN
C       PLOT TRIAL ESTIMATED STRESS HISTORY
C *********                                                    *******
150   WRITE (6,1150)
      WRITE (8,1150)
1150  FORMAT(/'     DO YOU WANT A PLOT OF ACTUAL RECORD AND TRIAL'
     @    ,' RECORD?  ')
      READ (5,1002) IANS
      WRITE (8,4002) IANS
      IF (IANS .EQ. 'N') GO TO 270
      LS = 1
      CALL RECPLT (LS,NPT,TACTL,YACTL,NHIST,THIST,YHIST,YHORGG,YRCOMP,
     @  IDENT,XMIN,XMAX)
C *********                                                    *******
      WRITE (6,1205)
      WRITE (8,1205)
1205  FORMAT(/'     WANT TO MODIFY RECORD? ',/,
     @     '      -N- EXITS WITHOUT WRITING ANY OUTPUT FILES')
      READ (5,1002) IANS
      WRITE (8,4002) IANS
      IF (IANS .EQ. 'N') GO TO 830
270   IF (IANSH .NE. 'Y') GO TO 300
      CALL HORGAGE(0,THIST,YHIST,NHIST,DT,TACTL,YHORGG,1,NPT,RADIUS,SSP)
      WRITE (8,1275)
      WRITE (6,1275)
1275  FORMAT(/'     WANT TO PLOT ACTUAL RECORD AND STRESS HISTORY',/,
     @     '      OBTAINED FROM HORIZONTAL GAGE DATA?  ')
      READ (5,1002) IANS
      WRITE (8,4002) IANS
      IF (IANS .EQ. 'N') GO TO 300
C       GRAPH THE SMEARED RECORD
      LS = 2
      CALL RECPLT (LS,NPT,TACTL,YACTL,NHIST,THIST,YHIST,YHORGG,YRCOMP,
     @  IDENT,XMIN,XMAX)
C *********                                                    *******
C       COMPUTE STRESS RECORD FROM INITIAL ESTIMATED STRESS HISTORY
C *********                                                    *******
300   OMEGA=2.*PI/TAU
      BETA=FD*OMEGA
      TAU0=TAU
      IF (IANSH .NE. 'Y') CALL RUNG(IBUG,BETA,OMEGA,THIST,
     @    YHIST,NHIST,DT,1,NPT,TACTL,YRCOMP)
      IF (IANSH .EQ. 'Y') CALL RUNG(IBUG,BETA,OMEGA,TACTL,
     @    YHORGG,NPT,DT,1,NPT,TACTL,YRCOMP)
310   WRITE (6,1310)
      WRITE (8,1310)
1310  FORMAT (/'     WANT TO PLOT STRESS RECORD, ESTIMATED HISTORY,'
     @        ,' AND COMPUTED?  ')
      READ (5,1002) IANS
      WRITE (8,4002) IANS
      IF (IANS .NE. 'Y') GO TO 400
      LS = 3
      CALL RECPLT (LS,NPT,TACTL,YACTL,NHIST,THIST,YHIST,YHORGG,YRCOMP,
```

PROGRAM RECFIT (Continued)

```
     @  IDENT,XMIN,XMAX)
C
C *********                                                       *******
C        BEGIN MODIFICATION OF ESTIMATED STRESS HISTORY.
C                SELECT ONE SHOCK REGION AT A TIME.
C *********                                                       *******
400   WRITE (6,1402)
      WRITE (8,1402)
1402  FORMAT(/'    WANT TO EXAMINE AND MODIFY RECORD IN DETAIL?
     @ /,'      -N- WRITES OUTPUT FILE AND PREPARES TO EXIT')
      READ (5,1002) IANS
      WRITE (8,4002) IANS
      IF (IANS .EQ. 'N') GO TO 795
C *********                                                       *******
C        REQUEST PLOT RECORD, TRIAL STRESS HISTORY, COMPUTED RECORD
C *********                                                       *******
410   WRITE (6,1310)
      WRITE (8,1310)
      READ (5,1002) IANS
      WRITE (8,4002) IANS
      IF (IANS .NE. 'Y') GO TO 440
415   LS = 3
      CALL RECPLT (LS,NPT,TACTL,YACTL,NHIST,THIST,YHIST,YHORGG,YRCOMP,
     @  IDENT,XMIN,XMAX)
      WRITE (8,1417)
      WRITE (6,1417)
1417  FORMAT (/'    WANT TO REPLOT WITH DIFFERENT SCALES TO EXAMINE A'
     @     ,' SMALL REGION?  ')
      READ (5,1002) IANS
      WRITE (8,4002) IANS
      IF (IANS .EQ. 'Y') GO TO 415
      WRITE (8,1418)
      WRITE (6,1418)
1418  FORMAT ('    IS RECORD FINISHED?  WANT TO EXIT?')
      READ (5,1002) IANS
      WRITE (8,4002) IANS
      IF (IANS .EQ. 'Y') GO TO 795
C *********                                                       *******
C        FIND SHOCKS IN THE STRESS RECORD
C ***********                                                     *******
440   TWF=TAU/6.
      LS = 0
      CALL FNDSHK(LS,NPT,TACTL,YACTL,NSHOCK,DELTS,ISHOCK,DT,TAU)
      IF (LS .EQ. 10) GO TO 950
C *********                                                       *******
C        DEFINE THE INTERVAL FOR EXAMINATION AND MODIFICATION
C *********                                                       *******
      WRITE (8,1440)
      WRITE (6,1440)
1440  FORMAT(/'    ENTER TIME INTERVAL FOR CHANGING RECORD - TBEG,TEND'
     @   ' (SEC)',/,7X,'THREE POINTS ARE USED, BEGINNING WITH TBEG')
      READ (5,*) TBEG,TEND
      WRITE (8,4440) TBEG,TEND
4440  FORMAT (' ->',1X,1PE7.1,',',E8.1)
C        FIND WINDOW CORRESPONDING TO TBEG, TEND.
      TEND = TBEG + 3.*TAU
      IWINDO = (TBEG-TACTL(1))/DT +1.
      JWINDO = (TEND-TACTL(1))/DT +2.
      IF (IWINDO .GE. 1 .AND. IWINDO .LE. NPT-1) GO TO 450
      WRITE (8,1445) IWINDO,TBEG,TEND,TACTL(1),TACTL(NPT)
```

PROGRAM RECFIT (Continued)

```
      WRITE (6,1445) IWINDO,TBEG,TEND,TACTL(1),TACTL(NPT)
 1445 FORMAT ('     INAPPROPRIATE TIMES FOR WINDOW.  IWINDOW=',I5,
     @  '  TBEG,TEND=',1P2E12.5/'    TIME RANGE OF RECORD IS FROM '
     @  E12.5,' TO ',E12.5)
      GO TO 440
450   JWINDO = MIN(MAX(IWINDO+10,JWINDO),NPT)
      IPLT=0
C **********                                                    *******
C         FIND INDICES OF THIST POINTS THAT LIE IN THE INTERVAL FROM
C           TBEG TO TEND
C **********                                                    *******
      NHIST1 = NHIST-1
      DO 460 N = 1,NHIST1
      NB = N
      IF (THIST(N+1) .GT. TBEG) GO TO 465
460   CONTINUE
465   NB = MIN(NB,NHIST-4)
      DO 470 N = NB,NHIST
      NE = N
      IF (THIST(N) .GT. TEND) GO TO 475
470   CONTINUE
475   NE = MIN(NHIST,MAX(NE,NB+1))
      DO 485 I=1,7
      GO TO (478,478,478,478,480,480,480) I
478   VA0(I)=THIST(NB+I-1)
      GO TO 485
480   VA0(I)=YHIST(NB+I-4)
485   CONTINUE
C **********                                                    *******
C         PLOT REQUEST FOR RECORD, ESTIMATED HISTORY, COMPUTED RECORD
C **********                                                    *******
490   WRITE (6,1310)
      WRITE (8,1310)
      WRITE (8,4002) IANS
      READ (5,1002) IANS
      IF (IANS .NE. 'Y') GO TO 600
      LS = 13
      IF (IPLT .EQ. 0) LS=LS-10
      CALL RECPLT (LS,NPT,TACTL,YACTL,NHIST,THIST,YHIST,YHORGG,YRCOMP,
     @  IDENT,XMIN,XMAX)
      IPLT=1
C *********                                                     *******
C       COMPUTE VARIANCE BETWEEN ACTUAL AND COMPUTED VALUES WITHIN WINDOW
C *********                                                     *******
600   CALL VARIAN(YACTL,YRCOMP,IWINDO,JWINDO,V0)
      WRITE (8,1605) V0
      WRITE (6,1605) V0
1605  FORMAT('     VARIANCE V0 =',1PE12.3)
C
      WRITE (8,1620) FD,TAU
      WRITE (6,1620) FD,TAU
1620  FORMAT(/'     FR. DAMP =',1PE11.3,2X,'PERIOD =',E11.3)
C **********                                                    *******
C         CALL RECOPT TO DETERMINE THE EFFECT OF VARYING SOME OF THE
C         COORDINATE TIMES AND AMPLITUDES, FREQUENCY AND DAMPING OF THE
C         GAGE.
C *********                                                     *******
      LS = 0
      WRITE (8,1622) TBEG,TEND
      WRITE (6,1622) TBEG,TEND
```

PROGRAM RECFIT (Continued)

```
1622 FORMAT (/'    FOR TIME INTERVAL(',1PE11.3,',',E11.3,')')
     CALL RECOPT (LS,IANSH,TBEG,TEND,TAU,FD,NPT,TACTL,YACTL,
    @  NHIST,THIST,YHIST,V0,LABEL,DT,YHORGG,YRCOMP)
C *********                                                       *******
C        ALTER THE ESTIMATED HISTORY, USING THE DERIVATIVE INFORMATION
C *********                                                       *******
     WRITE (8,1661)
     WRITE (6,1661)
1661 FORMAT ('    WANT TO CHANGE THE WINDOW?  ')
     READ (5,1002) IANSA
     WRITE (8,4002) IANSA
     IF (IANSA .EQ. 'Y') GO TO 645
     WRITE (8,1660)
     WRITE (6,1660)
1660 FORMAT('    WANT TO CHANGE ANY VALUE OF TRIAL RECORD?  ')
     READ (5,1002) IANS
     WRITE (8,4002) IANS
     IF (IANS .EQ. 'Y') GO TO 700
645  DO 650 I=1,9
650  VA(I)=0.
     GO TO 765
C
700  WRITE (6,1727)
     WRITE (8,1727)
1727 FORMAT('    TO CHANGE ANY VALUE ENTER THE "I" VALUE FOR THE',
    @    '    VARIABLE' /7X,'0 - TO EXIT CHANGE LOOP')
     READ (5,*) I
     WRITE (8,4727) I
4727 FORMAT (' ->',1X,I1)
     IF (I .EQ. 0) GO TO 730
C
     WRITE (8,1728)
     WRITE (6,1728)
1728 FORMAT('    ENTER NEW VALUE OF VARIABLE BEING CHANGED')
     READ (5,*) VA(I)
     WRITE (8,4720) VA(I)
4720 FORMAT (' ->',1X,1PE12.3)
     WRITE (8,1720) (I,LABEL(I),VA0(I),VA(I),I=1,9)
     WRITE (6,1720) (I,LABEL(I),VA0(I),VA(I),I=1,9)
1720 FORMAT('    I=',I2,2X,A6,'(ORIGINAL)=',1PE12.3,'  (NEW)=',E12.3)
     GO TO 700
C *********                                                       *******
C         PUT CHANGED VALUES INTO ARRAY
C *********                                                       *******
730  DO 750 I=1,9
     IF (VA(I) .EQ. 0.) GO TO 750
     IF (I .LE. 4) THIST(NB+I-1)=VA(I)
     IF (I .GT. 4 .AND. I .LE. 7) YHIST(NB+I-4)=VA(I)
     IF (I .NE. 8) GO TO 740
     FD=VA(I)
     BETA=FD*2.*PI/TAU0
740  IF (I .NE. 9) GO TO 750
     TAU=VA(I)
     OMEGA=2.*PI/TAU
750  CONTINUE
C *********                                                       *******
C       COMPUTE RECORD BASED ON NEW VALUES OF YHIST AND THIST
C *********                                                       *******
     IF (IANSH .NE. 'Y') GO TO 760
     CALL HORGAGE(1,THIST,YHIST,NHIST,DT,TACTL,YHORGG,IWINDO,
```

PROGRAM RECFIT (Continued)

```
     @    JWINDO,RADIUS,SSP)
      CALL RUNG(IBUG,BETA,OMEGA,TACTL,YHORGG,NPT,DT,IWINDO,
     @    JWINDO,TACTL,YRCOMP)
      GO TO 490
760   CALL RUNG(IBUG,BETA,OMEGA,THIST,YHIST,NHIST,DT,IWINDO,
     @    JWINDO,TACTL,YRCOMP)
      GO TO 490
C *********                                                     *******
C     END OF ITERATION FOR EACH TIME INTERVAL IN THE RECORD
C     COMPUTE RECORD BASED ON FINAL ESTIMATE OF THE STRESS HISTORY
C ********                                                      *******
765   IF (IANSH .NE. 'Y') GO TO 770
      CALL HORGAGE(1,THIST,YHIST,NHIST,DT,TACTL,YHORGG,1,NPT,
     @    RADIUS,SSP)
      CALL RUNG(IBUG,BETA,OMEGA,TACTL,YHORGG,NPT,DT,1,NPT,TACTL,
     @    YRCOMP)
      GO TO 790
770   CALL RUNG(IBUG,BETA,OMEGA,THIST,YHIST,NHIST,DT,1,NPT,TACTL,
     @    YRCOMP)
790   TAU0=2.*PI/OMEGA
C ***********                                                   *******
C     WRITE RESTART FILE
C *********                                                     *******
      REWIND (3)
      WRITE (3,1008) IDENT
      WRITE (3,1021) NHIST,FD,TAU0,TW,IANSH,RADIUS,SSP
      WRITE (3,1019) (THIST(I),YHIST(I),I=1,NHIST)
      IF (IANSA .EQ. 'Y') GO TO 440
C *********                                                     *******
C      PLOT RECORD, ESTIMATED HISTORY, AND COMPUTED RECORD
C **********                                                    *******
      WRITE (8,1312)
      WRITE (6,1312)
1312  FORMAT (/'    WANT TO PLOT STRESS RECORD, ESTIMATED HISTORY, AND'
     @ '       COMPUTED?  ',/,'      -N-  SENDS TO END')
      READ (5,1002) IANS
      WRITE (8,4002) IANS
      IF (IANS .EQ. 'N') GO TO 795
      LS = 3
      CALL RECPLT (LS,NPT,TACTL,YACTL,NHIST,THIST,YHIST,YHORGG,YRCOMP,
     @  IDENT,XMIN,XMAX)
      WRITE (8,1800)
      WRITE (6,1800)
1800  FORMAT('    WANT TO GO BACK TO MODIFY RECORD FURTHER?'
     @    ,/,'          -N- SEND TO END')
      READ (5,1002) IANS
      WRITE (8,4002) IANS
      IF (IANS .EQ. 'Y') GO TO 410
C *********                                                     *******
C      SAVE DATA FROM FINAL TRIAL RECORD ON FOR004
C *********                                                     *******
795   REWIND 4
      WRITE (4,1008) IDENT
      WRITE (4,1021) NHIST
      WRITE (4,1020) (THIST(I),YHIST(I), I=1,NHIST)
C *********                                                     *******
C     MAKE HARD COPIES OF PLOTTED RESULTS
C **********                                                    *******
830   WRITE (6,1830)
      WRITE (8,1830)
```

PROGRAM RECFIT (Continued)

```
1830  FORMAT('    WANT HARD COPIES OF RESULTS?')
      READ (5,1002) IANS
      WRITE (8,4002) IANS
      IF (IANS .EQ. 'N') GO TO 900
C       CALL TO CLOSE OUT PLOTTING
      CALL GPLOT(0.,0.,999)
C       CALL TO INITIALIZE PLOTTING ON HARD COPY DEVICE
      CALL GINITL(0)
C
850   LS = -3
      CALL RECPLT (LS,NPT,TACTL,YACTL,NHIST,THIST,YHIST,YHORGG,YRCOMP,
     @  IDENT,XMIN,XMAX)
C
      LS = -6
      IF (IANSH .EQ. 'Y') LS = -7
      CALL RECPLT (LS,NPT,TACTL,YACTL,NHIST,THIST,YHIST,YHORGG,YRCOMP,
     @  IDENT,XMIN,XMAX)
      WRITE (6,9860)
9860  FORMAT (/' WANT MORE HARD COPIES WITH DIFFERENT SCALES?')
      READ (5.1002) IANS
      IF (IANS .EQ. 'Y') GO TO 850
C
C       CALL TO CLOSE PLOTTING HARD COPIES
      CALL GPLOT(0.,0.,999)
C         CALL TO INITIALIZE PLOTTING ON TERMINAL
      CALL GINITL(1)
C *********                                                   *******
C     INTEGRATE ACCLERATION RECORD FOR VELOCITY
C **********                                                  *******
900   WRITE (6,1905)
      WRITE (8,1905)
1905  FORMAT('    DO YOU WANT TO CALCULATE VELOCITY?')
      READ (5,1002) IANS
      WRITE (8,4002) IANS
      IF (IANS .NE. 'Y') GO TO 950
C     CALCULATE VELOCITY FROM ACTUAL RECORD
      YRCOMP(1) = 0.
      DO 910 I=2,NPT
      YRCOMP(I)=YRCOMP(I-1)+0.5*DT*(YACTL(I-1)+YACTL(I))
910   CONTINUE
C     CALCULATE VELOCITY FROM TRIAL RECORD
      YVELOC(1) = 0.
      DO 920 I=2,NHIST
      YVELOC(I) = YVELOC(I-1)+0.5*(THIST(I)-THIST(I-1))*
     @  (YHIST(I-1)+YHIST(I))
920   CONTINUE
      LS = 5
      CALL RECPLT (LS,NPT,TACTL,YACTL,NHIST,THIST,YVELOC,YHORGG,YRCOMP,
     @  IDENT,XMIN,XMAX)
      GO TO 950
9999  WRITE (6,997) FILENAME3
997   FORMAT (' ERROR IN OPENING ',A15)
950   CALL GPLOT(0.,0.,999)
      CLOSE (2)
      CLOSE (3)
      CLOSE (4)
      CLOSE (9)
      STOP
C       FORMATS
1002  FORMAT (A1)
```

PROGRAM RECFIT (Continued)

```
1008  FORMAT (A55)
1019  FORMAT (1P8E14.5)
1020  FORMAT(1P2E11.3)
1021  FORMAT (I5,3E12.5,4X,A1,2E12.5)
      END
```

PROGRAM RECFIT (Concluded)

```
      SUBROUTINE FNDSHK (LS,NPT,TIME,STRESS,NSHOCK,DELTS,IBEG,
     +  DT,PERIOD)
C    *****
C       SUBROUTINE TO FIND SHOCK FRONT
C    *****
      IMPLICIT REAL*4 (A-H,O-Z)
      DIMENSION TIME(1),STRESS(1),DELTS(1),IBEG(1)
      DIMENSION IBLOCL(10),DSLOCL(10)
C    *****
C       INITIALIZE
C    *****
      LWINDO = 3. * PERIOD/DT + 1.
      NSTEP = PERIOD/(4.*DT) + 1.
      IBEGIN = 1
      IBEGMX = 1
      DELTAS = 0.0
      NSHOCK = 0
C    *****
C       SEARCH FOR A SHOCK FRONT
C    *****
  100 DS = STRESS(IBEGIN+NSTEP) - STRESS(IBEGIN)
      IF (DS .LE. DELTAS) GO TO 125
      DELTAS = DS
      IBEGMX = IBEGIN
  125 IBEGIN = IBEGIN + 1
      IF ( IBEGIN+NSTEP .LT. IBEGMX+LWINDO .AND.
     +      IBEGIN+NSTEP .LT. NPT) GO TO 100
C    *****
C       STORE SHOCK FRONT DATA
C    *****
      ISHK = 1
      IF (NSHOCK .EQ. 0) GO TO 200
      DO 175 IS = 1,NSHOCK
      IF (DSLOCL(IS) .GE. DELTAS) GO TO 175
      ISHK = IS
      DO 150 I = IS,NSHOCK
      J = NSHOCK+IS-I
      IF (J .GE. 10) GO TO 150
      DSLOCL(J+1) = DSLOCL(J)
      IBLOCL(J+1) = IBLOCL(J)
  150 CONTINUE
      GO TO 200
  175 CONTINUE
      IF (NSHOCK .GE. 10) GO TO 225
      ISHK = NSHOCK+1
  200 DSLOCL(ISHK) = DELTAS
      IBLOCL(ISHK) = IBEGMX
      NSHOCK = MIN(NSHOCK+1,10)
  225 IF ( IBEGIN + 2*NSTEP .GE. NPT) GO TO 250
      IBEGIN = IBEGIN+NSTEP
      IBEGMX = IBEGIN
      DELTAS = 0.
      GO TO 100
C    *****
C       ASSEMBLE SHOCK DATA INTO FORMAL PARAMETERS
C    *****
C 250 WRITE (6,1025) (N,DSLOCL(N),IBLOCL(N),N = 1,NSHOCK)
 250  NSHMAX = MIN (NSHOCK,2)
      DO 275 NS = 1,NSHMAX
      DELTS(NS) = DSLOCL(NS)
```

SUBROUTINE FNDSHK

```
  275 IBEG(NS) = IBLOCL(NS)
      L1 = IBEG(1)
      L2 = IBEG(2)
      WRITE (6,1027) TIME(L1),DELTS(1),TIME(L2),DELTS(2)
      WRITE (8,1027) TIME(L1),DELTS(1),TIME(L2),DELTS(2)
      RETURN
C       FORMATS
 1025 FORMAT (' N, DSLOCL(N), IBLOCL(N) = ',I3,1PE12.4,I8)
 1027 FORMAT (' 1st SHOCK AT T = ',1PE12.4,' STRESS JUMP = ',E12.4/
     +        ' 2nd SHOCK AT T = ',E12.4,' STRESS JUMP = ',E12.4)
      END
```

SUBROUTINE FNDSHK (Concluded)

```
      SUBROUTINE HORGAGE(NCALL,THIST,YHIST,NHIST,DT,TACTL,YHORGG,
     @  IWINDO,JWINDO,RADIUS,C)
C
C     CALCULATE STRESS HISTORY FROM GRADUAL LOADING ACROSS A CIRCULAR
C     GAGE USING A STEP LOADING THAT MOVES ACROSS THE GAGE AT VELOCITY C
C
      IMPLICIT REAL*4 (A-H,O-Z)
      DIMENSION THIST(1),YHIST(1),YHORGG(1),F(50),TAUF(50),TACTL(1)
      IF (NCALL .NE. 0) GO TO 60
      WRITE (8,1002)
      WRITE (6,1002)
1002  FORMAT('    ENTER GAGE RADIUS (CM)')
      READ (5,*), RADIUS
      WRITE (8,4004) RADIUS
4004  FORMAT (' ->',1X,F4.2)
      WRITE (6,1004)
      WRITE (8,1004)
1004  FORMAT('    ENTER SOUND SPEED (CM/SEC)')
      READ (5,*), C
      WRITE (8,4005) C
4005  FORMAT (' ->',1X,1PE7.1)
      ENTRY HRESTRT(NCALL,THIST,YHIST,NHIST,DT,TACTL,YHORGG,IWINDO,
     1  JWINDO,RADIUS,C)
      TWOPI=2.*3.14159265
      TAUMX=0.885*RADIUS/C
      NF=TAUMX/DT
      NF2=2*NF+1
      CON=C/(1.77*RADIUS)
      TBAR=RADIUS/C
      F1=0.
      TAUF(1)=-NF*DT
      DO 50 J=1,NF2
      IF (J .GT. 1) TAUF(J)=TAUF(J-1)+DT
      F0=F1
      F1=CON*TAUF(J)-SIN(TWOPI*(CON*TAUF(J)+0.5))/TWOPI
      F(J)=0.
      IF (J .NE. 1) F(J)=F1-F0
50    CONTINUE
C      WRITE(13,1040) (J, TAUF(J),F(J), J=1,NF2)
      WRITE(9,1040) (J, TAUF(J),F(J), J=1,NF2)
1040  FORMAT('     J        TAUF            F'/(I5,1P2E11.3))
C
C     CONSTRUCT STRESS HISTORY
C
60    IT=1
      IT0=1
C      WRITE (13,9915) (THIST(I), I=320,350)
9915  FORMAT(' ===HORGAGE, THIST(320,350) = :'/(1P6E13.5))
      DO 200 I = IWINDO,JWINDO
      T = TACTL(I)
      YHORGG(I) = 0.
      IF (T-TAUMX .LT. THIST(IT0)) GO TO 80
70    IF (T-TAUMX .LT. THIST(IT0+1)) GO TO 80
      IT0=IT0+1
      GO TO 70
80    IT=IT0
      DO 100 J=1,NF2
      IF (T+TAUF(J) .LT. THIST(IT) .OR. T+TAUF(J) .GT. THIST(NHIST))
     @  GO TO 100
      IF (T+TAUF(J) .GE. THIST(IT+1) .AND. IT+1 .LE. NHIST) IT=IT+1
```

SUBROUTINE HORGAGE

```
C        IF (THIST(IT+1)-THIST(IT) .LE. 1.0E-6) WRITE (13,9914)
C       @  J,NF2,TAUF(J),IT,T,
C       @  THIST(IT),THIST(IT+1),YHORGG(I),F(J),YHIST(IT),YHIST(IT+1)
9914   FORMAT(' **HORGAGE, J,NF2='2I5,' TAUF(J)='1PE11.3,
      @     ' IT =',I5,' T=',E11.3/' THIST(IT),
      @  THIST(IT+1)=',2E11.3/'  YHORGG(I),F(J)='2E11.3,
      2   ' YHIST(IT),YHIST(IT+1)=',2E11.3)
       YHORGG(I)=YHORGG(I)+F(J)*(YHIST(IT)+(T+TAUF(J)-THIST(IT))*
      @  (YHIST(IT+1)-YHIST(IT))/(THIST(IT+1)-THIST(IT)))
100    CONTINUE
200    CONTINUE
C
       RETURN
       END
```

SUBROUTINE HORGAGE (Concluded)

```
      SUBROUTINE MINMAX (YACTL,NPT,YMIN,YMAX)
      DIMENSION YACTL(1)
      YMIN = 2.E10
      YMAX = -2.E10
      DO 610 I=1,NPT
      IF (YACTL(I) .GT. YMAX) YMAX = YACTL(I)
      IF (YACTL(I) .LT. YMIN) YMIN = YACTL(I)
610   CONTINUE
      RETURN
      END
```

SUBROUTINE MIN MAX

```
      SUBROUTINE RECOPT (LS,IANSH,TBEG,TEND,TAU,FD,NPT,TACTL,YACTL,
     @  NHIST,THIST,YHIST,V0,LABEL,DT,YHORGG,YRCOMP)
C        VARY ONE AT A TIME THE S,T COORDINATES OF POINTS IN THE ESTIMATED
C          STRESS HISTORY, AND FREQUENCY AND DAMPING OF THE GAGE; COMPUTE
C          THE STRESS RECORDS FROM THE MODIFIED HISTORIES, AND THE
C          VARIANCES FROM THE ACTUAL RECORD.  COMPUTE THE FINITE DIFF-
C          ERENCE APPROXIMATIONS TO THE DERIVATIVES OF THE VARIANCE WITH
C          RESPECT TO THE CHANGE IN THE ALTERED VARIABLE.
C
      IMPLICIT REAL*4 (A-H,O-Z)
      CHARACTER*1 IANSH
      CHARACTER*9 LABEL(9)
      DIMENSION THIST(1),YHIST(1),TACTL(1),YACTL(1),VALUE(2,9),
     @  DEL(2,9),DER(2,9),VARNCE(2,9),YHORGG(1),YRCOMP(1),DELMIN(9)
      DATA PI/3.14159265/
      DATA DELMIN /4*1.E-6, 3*100., 2*0./
      IBUG = 0
      DELFAC = 0.1
      ICHUZ = 0
      ISIGN = 1
      VMIN = V0
      OMEGA = 2.*PI/TAU
      BETA = FD*OMEGA
      IWINDO = (TBEG-TACTL(1))/DT +1.
      JWINDO = (TEND-TACTL(1))/DT +2.
      IF (IWINDO .GE. 1 .AND. IWINDO .LE. NPT-1) GO TO 100
      WRITE (8,1005) IWINDO,TBEG,TEND,TACTL(1),TACTL(NPT)
      WRITE (6,1005) IWINDO,TBEG,TEND,TACTL(1),TACTL(NPT)
 1005 FORMAT ('  INAPPROPRIATE TIMES FOR WINDOW.  IWINDOW=',I5,
     @  ' TBEG,TEND=',1P2E12.5/'  TIME RANGE OF RECORD IS FROM '
     @  E12.5,' TO ',E12.5)
      LS=-1
      RETURN
C      WRITE (13,4150)
C      WRITE (13,4360) (THIST(I),YHIST(I),I=320,350)
4150  FORMAT (' RECOPT START :'
     @      ' THIST(I),YHIST(I), I = 320,350')
100   JWINDO = MIN(MAX(IWINDO+10,JWINDO),NPT)
C      WRITE (13,4100) IWINDO,JWINDO
4100  FORMAT (' IWINDO, JWINDO =',2I6,' TACTL(I),I=IWINDO,JWINDO')
C      WRITE (13,4110) (TACTL(I),I=IWINDO,JWINDO)
4110  FORMAT (1P6E13.5)
      DO 200 I = 2,NHIST
      IHIST = I-1
      IF (THIST(I) .GT. TBEG) GO TO 210
200   CONTINUE
210   IHIST = MIN (IHIST,NHIST-4)
      DO 240 I = IHIST,NHIST
      JHIST =I
      IF (THIST(I) .GT. TEND) GO TO 250
240   CONTINUE
250   JHIST = MIN (NHIST,MAX (JHIST,IHIST+1))
C      IWIN = 1
C      JWIN = NPT
C      IF (LS .EQ. 0) GO TO 300
      IWIN = IWINDO
      JWIN = JWINDO
300   DO 395 MINPLU = 1,2
      DO 390 I=1,9
      IF (LS .LE. 1) GO TO 310
```

SUBROUTINE RECOPT

```
      IF (I .EQ. 1 .OR. I .EQ. 8 .OR. I .EQ. 9) GO TO 390
310   GO TO (320,320,320,320,330,330,330,340,350) I
320   VALUE(MINPLU,I)=THIST(IHIST+I-1)
      IF (IHIST+I .GT. 2) DELTAT=THIST(IHIST+I-1)-THIST(IHIST+I-2)
      IF (IHIST+I .LE. NHIST) DELTAT=MIN(DELTAT,THIST(IHIST+I)-
     1  THIST(IHIST+I-1))
      DELTAT = MAX(DELMIN(I),DELTAT)
      DEL(MINPLU,I)=DELFAC*DELTAT
      THIST(IHIST+I-1)=THIST(IHIST+I-1)+DEL(MINPLU,I)
      GO TO 360
330   VALUE(MINPLU,I)=YHIST(IHIST+I-4)
      DELTAY = YHIST(IHIST+I-4)-YHIST(IHIST+I-5)
      IF (IHIST+I .LE. NHIST) DELTAY=MIN(DELTAY,YHIST(IHIST+I-3)-
     1  YHIST(IHIST+I-4))
      DELTAY = MAX(DELTAY,DELMIN(I))
      DEL(MINPLU,I)=DELFAC*DELTAY
      YHIST(IHIST+I-4)=YHIST(IHIST+I-4)+DEL(MINPLU,I)
      GO TO 360
340   VALUE(MINPLU,I)=FD
      DEL(MINPLU,I)=DELFAC*FD
      FD=FD+DEL(MINPLU,I)
      BETA=FD*2.*PI/TAU
      GO TO 360
350   VALUE(MINPLU,I)=TAU
      DEL(MINPLU,I)=DELFAC*TAU
      TAU=TAU+DEL(MINPLU,I)
      OMEGA=2.*PI/TAU
      BETA = FD*2.*PI/TAU
360   CONTINUE
C *********                                                    *******
C                COMPUTE RECORD AND VARIANCE FOR EACH PARAMETER VARIATION
      IF (IANSH .NE. 'Y') GO TO 361
C      WRITE (13,4350)
4350  FORMAT (' RECOPT BEFORE CALL TO HORGAGE:'
     @      ' THIST(K),YHIST(K),  K = 320,350')
C      WRITE (13,4360) (THIST(K),YHIST(K),K = 320,350)
4360  FORMAT (1P2E13.5)
      CALL HORGAGE(2,THIST,YHIST,NHIST,DT,TACTL,YHORGG,IWIN,JWIN,
     @   RADIUS,SSP)
      CALL RUNG(IBUG,BETA,OMEGA,TACTL,YHORGG,NPT,DT,
     @   IWIN,JWIN,TACTL,YRCOMP)
      GO TO 362
361   CALL RUNG(IBUG,BETA,OMEGA,THIST,YHIST,NHIST,DT,
     @   IWIN,JWIN,TACTL,YRCOMP)
362   CALL VARIAN(YACTL,YRCOMP,IWINDO,JWINDO,VARNCE(MINPLU,I))
      DER(MINPLU,I)=0.
      IF (VARNCE(MINPLU,I) .NE. V0)
     @   DER(MINPLU,I)=V0/((V0-VARNCE(MINPLU,I))/DEL(MINPLU,I))
      IF (VARNCE(MINPLU,I) .GT. VMIN-1.) GO TO 364
      VMIN = VARNCE(MINPLU,I)
      ICHUZ = I
      ISIGN = MINPLU
C      RETURN TO ORIGINAL VALUES OF EACH PARAMETER
364   GO TO (365,365,365,365,370,370,370,375,380) I
365   THIST(IHIST+I-1)=VALUE(MINPLU,I)
      GO TO 390
370   YHIST(IHIST+I-4)=VALUE(MINPLU,I)
      GO TO 390
375   FD=VALUE(MINPLU,I)
      BETA=FD*2.*PI/TAU
```

SUBROUTINE RECOPT (Continued)

```
      GO TO 390
380   TAU=VALUE(MINPLU,I)
      OMEGA=2.*PI/TAU
      BETA = FD*2.*PI/TAU
390   CONTINUE
      DELFAC = -DELFAC
395   CONTINUE
      IF (LS .NE. 0) GO TO 397
      WRITE (8,1053)
      WRITE (6,1053)
1053  FORMAT (/'  I',2X,'LABEL(I)',4X,'VALUE(I)',4X,'DEL(1)',5X,
     @  'DEL(2)',5X,'VARIANCE(1)',1X,'VARIANCE(2)')
      WRITE (8,1054) (I,LABEL(I),VALUE(1,I),DEL(1,I),DEL(2,I),
     @   VARNCE(1,I),VARNCE(2,I),I=1,9)
      WRITE (6,1054) (I,LABEL(I),VALUE(1,I),DEL(1,I),DEL(2,I),
     @   VARNCE(1,I),VARNCE(2,I),I=1,9)
1054  FORMAT (1X,I2,1X,A9,1X,1P5E12.3)
C
C       COMPLETION FOR LS=0, ADVISORY CHANGE INFORMATION ONLY
      RETURN
C *********                                                    *******
C       ALTER ONE PARAMETER OF THE ESTIMATED HISTORY
397   IF (ICHUZ .EQ. 0) GO TO 430
      GO TO (400,400,400,400,  408,408,408,  415, 418) ICHUZ
400   THIST(IHIST+ICHUZ-1) = THIST(IHIST+ICHUZ-1)+DEL(ISIGN,ICHUZ)
      GO TO 425
408   YHIST(IHIST+ICHUZ-4) = YHIST(IHIST+ICHUZ-4)+DEL(ISIGN,ICHUZ)
      GO TO 425
415   FD = FD+DEL(ISIGN,ICHUZ)
      BETA = FD*2.*PI/TAU
      GO TO 425
418   TAU = TAU+DEL(ISIGN,ICHUZ)
      OMEGA = 2.*PI/TAU
425   CONTINUE
430   DELFAC = ABS(DELFAC)
      IF (DELFAC .LT. 0.01) GO TO 500
      IF (ICHUZ .EQ. 0) DELFAC = 0.5*DELFAC
      ICHUZ = 0
      GO TO 300
C *********                                                    *******
C       ENDING ROUTINE
500   IF (IANSH .NE. 'Y') GO TO 505
      CALL HORGAGE(1,THIST,YHIST,NHIST,DT,TACTL,YHORGG,IWIN,JWIN,RADIUS,
     @  SSP)
      CALL RUNG(IBUG,BETA,OMEGA,TACTL,YHORGG,NPT,DT,
     @   IWIN,JWIN,TACTL,YRCOMP)
      GO TO 510
505   CALL RUNG(IBUG,BETA,OMEGA,THIST,YHIST,NHIST,DT,
     @   IWIN,JWIN,TACTL,YRCOMP)
510   CALL VARIAN(YACTL,YRCOMP,IWINDO,JWINDO,V0)
      END
```

SUBROUTINE RECOPT (Concluded)

```
      SUBROUTINE RECPLT (LS,NPT,TACTL,YACTL,NHIST,THIST,YHIST,YHORGG,
     @ YRCOMP,IDENT,XMIN,XMAX)
C       PLOT SEVERAL HISTORIES FOR THE RECFIT PROGRAM
C       LS=1  ACTUAL RECORD, AND TRIAL STRESS HISTORY
C       LS=2  SMEARED ESTIMATE OF HORIZONTAL STRESS HISTORY
C       LS=3  ACTUAL RECORD, TRIAL HISTORY, COMPUTED RECORD
C       LS=4  SMEARED HISTORY, TRIAL HISTORY,
C               AND COMPUTED RECORD
C       LS=5  PLOT OF ACCELERATION AND VELOCITY
C       LS=6  PLOT OF ACTUAL RECORD AND COMPUTED RECORD
C       LS=7  PLOT OF ACTUAL RECORD, SMEARED HISTORY, AND
C                COMPUTED RECORD
C
      DIMENSION IA(7),TACTL(1),YACTL(1),THIST(1),YHIST(1),YHORGG(1),
     1 YRCOMP(1)
      CHARACTER TITLE(3)*80, IDENT*50
      DATA TITLE(2)/'TIME -- *SEC$'/
      DATA IA/-2,5*0,5/
      YMIN=0.
      YMAX=0.
50    TITLE(1) = IDENT
      LSM=MOD(ABS(LS),10)
      GO TO (100,200,300,400,500,600,700,800) LSM
100   TITLE(3) = 'STRESS - ACTUAL RECORD, TRIAL HISTORY'
      IF (ABS(LS) .GT. 10) GO TO 190
      WRITE (8,1022) XIMN,XMAX
      WRITE (6,1022) XMIN,XMAX
      READ (5,1002),IANS
      WRITE (8,4100) IANS
4100  FORMAT (' ->',1X,A1)
      IF (IANS .EQ. 'N' ) GO TO 190
      WRITE (8,1024)
      WRITE (6,1024)
      READ (5,*),XMIN,XMAX
      WRITE (8,4024) XMIN,XMAX
4024  FORMAT (' ->',1X,1P2E12.3)
190   IA(1) = 1
C      CALL JFRAME
      CALL GRAPH4(TACTL,YACTL,NPT,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
C      IA(1)=-4
      IA(1) =-2
      CALL GRAPH4(THIST,YHIST,NHIST,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
      RETURN
C
C       LS = 2 PLOT OF SMEARED STRESS HISTORY
200   TITLE(3) = ' STRESS - ACTUAL AND SMEARED ESTIMATED HISTORY'
      IF (ABS(LS) .GT. 10) GO TO 220
      WRITE (8,1022) XMIN,XMAX
      WRITE (6,1022) XMIN,XMAX
      READ (5,1002), IANS
      WRITE (8,4100) IANS
      IF (IANS .EQ. 'N' ) GO TO 220
      WRITE (8,1024)
      WRITE (6,1024)
      READ (5,*), XMIN,XMAX
      WRITE (8,4024) XMIN,XMAX
C220   CALL JFRAME
220   IA(1) = 1
      IA(3) = 0
      CALL GRAPH4(TACTL,YACTL,NPT,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
```

SUBROUTINE RECPLT

```
      IA(3) = 2
C      IA(1)=-4
      IA(1) = -2
      CALL GRAPH4(TACTL,YHORGG,NPT,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
      RETURN
C
C       LS = 3
C       COMPOSITE PLOT OF ACTUAL RECORD, TRIAL STRESS HISTORY, AND
C          COMPUTED RECORD
300   TITLE(3) = ' STRESS - ACTUAL, ESTIMATED HIST, COMPUTED RECORD'
      IF (ABS(LS) .GT. 10) GO TO 320
      IF (LS .GT. 0) GO TO 305
      CALL MINMAX(YACTL,NPT,YMIN,YMAX)
      WRITE (8,9300)
      WRITE (6,9300)
9300  FORMAT (/'   ***   PLOTTING ACTUAL, EST., COMPUTED RECORDS')
305   WRITE (6,1022) XMIN,XMAX
      WRITE (8,1022) XMIN,XMAX
      READ (5,1002),IANS
      WRITE (8,4100) IANS
      IF (IANS .EQ. 'N') GO TO 320
      WRITE (8,1024)
      WRITE (6,1024)
      READ (5,*),XMIN,XMAX
      WRITE (8,4024) XMIN,XMAX
320   IA(1) = 1
      IA(3) = 0
      IF (LS .LT. 0) GO TO 325
C      CALL JFRAME
325   CALL GRAPH4(TACTL,YACTL,NPT,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
      IA(3) = 6
      CALL GRAPH4(THIST,YHIST,NHIST,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
C      IA(1)=-4
      IA(1) = -2
      IF (LS .LT. 0) IA(1)=-2
      IA(3) = 2
      CALL GRAPH4(TACTL,YRCOMP,NPT,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
      RETURN
C
C       LS = 4
C       PLOT OF RECORD, SMEARED HISTORY, AND COMPUTED  RECORD
C
400   TITLE(3) = ' STRESS - RECORD, SMEARED HISTORY, COMP. REC.'
      IF (ABS(LS) .GT. 10) GO TO 420
      IF (LS .GT. 0) GO TO 405
      CALL MINMAX(YACTL,NPT,YMIN,YMAX)
      WRITE (8,9400)
      WRITE (6,9400)
9400  FORMAT (/'   ***   PLOTTING RECORD, SMEARED HISTORY,',
     @     ' COMPUTED RECORD')
405   WRITE (6,1022) XMIN,XMAX
      WRITE (8,1022) XMIN,XMAX
      READ (5,1002),IANS
      WRITE (8,4100) IANS
      IF (IANS .EQ. 'N') GO TO 420
      WRITE (8,1024)
      WRITE (6,1024)
      READ (5,*),XMIN,XMAX
      WRITE (8,4024) XMIN,XMAX
420   IA(1) = 1
```

SUBROUTINE RECPLT (Continued)

```
      IA(3)=0
      IF (LS .LT. 0) GO TO 425
C      CALL JFRAME
425   CALL GRAPH4(TACTL,YACTL,NPT,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
      IA(3) = 3
      CALL GRAPH4(TACTL,YHORGG,NPT,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
C      IA(1)=-4
      IA(1) = -2
      IF (LS .LT. 0) IA(1) = -2
      IA(3)=2
      CALL GRAPH4(TACTL,YRCOMP,NPT,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
      RETURN
C
C       LS = 5
C       PLOT OF VELOCITY HISTORY COMPUTED FROM ACCELERATION
500   CONTINUE
      TITLE(3) = ' VELOCITY (COMPUTED) AND ACCELERATION RECORD'
      IF (ABS(LS) .GT. 10) GO TO 520
      WRITE (8,1022) XMIN,XMAX
      WRITE (6,1022) XMIN,XMAX
      READ (5,1002),IANS
      WRITE (8,4100) IANS
      IF (IANS .EQ. 'N') GO TO 520
      WRITE (8,1024)
      WRITE (6,1024)
      READ (5,*),XMIN,XMAX
      WRITE (8,4024) XMIN,XMAX
520   IA(1) = 1
      IA(3) = 0
C      CALL JFRAME
      CALL GRAPH4(TACTL,YACTL,NPT,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
      IA(3) = 1
      IA(1) = -2
      CALL GRAPH4(THIST,YHIST,NHIST,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
      RETURN
C
C     LS = 6
C       PLOT OF ACTUAL HISTORY AND BACK COMPUTED
C
600   TITLE(3) = ' STRESS - ACTUAL AND BACK COMPUTED'
      IF (ABS(LS) .GT. 10) GO TO 620
      IF (LS .GT. 0) GO TO 605
      CALL MINMAX(YACTL,NPT,YMIN,YMAX)
      WRITE (8,9600)
      WRITE (6,9600)
9600  FORMAT (/'   ***   PLOTTING ACTUAL AND COMPUTED RECORDS')
605   WRITE (6,1022) XMIN,XMAX
      WRITE (8,1022) XMIN,XMAX
      READ (5,1002),IANS
      WRITE (8,4100) IANS
      IF (IANS .EQ. 'N') GO TO 620
      WRITE (8,1024)
      WRITE (6,1024)
      READ (5,*),XMIN,XMAX
      WRITE (8,4024) XMIN,XMAX
620   CALL MINMAX (YACTL,NPT,YMIN,YMAX)
      IA(1) = 1
      IA(3) = 0
      CALL GRAPH4(TACTL,YACTL,NPT,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
      IA(1)=-2
```

SUBROUTINE RECPLT (Continued)

```
      IA(3) = 2
      CALL GRAPH4(TACTL,YRCOMP,NPT,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
      GO TO 800
C        LS = 7
C      PLOT OF STRESS RECORD, SMEARED HISTORY, AND COMPUTED
C         RECORD
700   TITLE(3) = ' STRESS - ACTUAL, SMEARED, AND COMPUTED REC.'
      IF (ABS(LS) .GT. 10) GO TO 720
      IF (LS .GT. 0) GO TO 705
      CALL MINMAX (YACTL,NPT,YMIN,YMAX)
      WRITE (8,9700)
      WRITE (6,9700)
9700  FORMAT (/'    ***   PLOTTING ACTUAL, SMEARED, AND COMPUTED'
     @      ,' RECORDS')
705   WRITE (6,1022) XMIN,XMAX
      WRITE (8,1022) XMIN,XMAX
      READ (5,1002),IANS
      WRITE (8,4100) IANS
      IF (IANS .EQ. 'N') GO TO 720
      WRITE (8,1024)
      WRITE (6,1024)
      READ (5,*),XMIN,XMAX
      WRITE (8,4024) XMIN,XMAX
720   IA(1) = 1
      IA(3)=0
      CALL GRAPH4(TACTL,YACTL,NPT,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
      IA(3)=3
      CALL GRAPH4(TACTL,YHORGG,NPT,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
      IA(1)=-2
      IA(3)=1
      CALL GRAPH4(TACTL,YRCOMP,NPT,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
C
C      LS = 8
C       PLOT FINAL ESTIMATED RECORD
C
800   TITLE(3) = ' STRESS - FINAL ESTIMATED RECORD'
      IF (ABS(LS) .GT. 10) GO TO 820
      IF (LS .LT. 0) WRITE (6,9800)
      IF (LS .LT. 0) WRITE (8,9800)
9800  FORMAT (/'    ***   PLOTTING FINAL RECORD')
      WRITE (8,1022) XIMN,XMAX
      WRITE (6,1022) XMIN,XMAX
      READ (5,1002),IANS
      WRITE (8,4100) IANS
      IF (IANS .EQ. 'N') GO TO 820
      WRITE (8,1024)
      WRITE (6,1024)
      READ (5,*),XMIN,XMAX
      WRITE (8,4024) XMIN,XMAX
820   IA(3)=0
      IA(1)=-2
      CALL GRAPH4(THIST,YHIST,NHIST,1,XMAX,XMIN,YMAX,YMIN,TITLE,IA)
      RETURN
1002  FORMAT (A1)
1022  FORMAT(/'     XMIN, XMAX =  ',1P2E11.3,'  WANT TO CHANGE THEM?  ')
1024  FORMAT(/'     ENTER XMIN,XMAX')
      END
```

SUBROUTINE RECPLT (Concluded)

```
      SUBROUTINE RECRED (LS,IDENT,IDAT,NPT,DT,YACTL,TACTL,FILENAME)
C       READ THE FILE CONTAINING THE GAGE RECORD
      IMPLICIT REAL*4 (A-H,O-Z)
      DIMENSION TACTL(1),YACTL(1)
      DIMENSION IVAR(5),IVARS(5)
      DATA IVAR/'(I5,','2E16','.8)',' ',' '/
      DATA IVARS/'(5E1','6.8)',' ',' ',' '/
      CHARACTER IDENT*50,FILENAME*20,IDAT*10,IANS*1
C *********                                                   *******
C               CHECK FOR FORMAT OF INPUT DATA
      NLINES = 1
      WRITE (8,1000)
      WRITE (6,1000)
      READ (5,1002) IANS
      WRITE (8,4000) IANS
4000  FORMAT (' ->',1X,A1)
      IF (IANS .EQ. 'Y') GO TO 100
C
C       PROVISION FOR DATA FILE NOT IN STANDARD FORM  -----------------
      WRITE (8,1004)
      WRITE (6,1004)
      READ (5,*),NLINES
      WRITE (8,4005) NLINES
4005  FORMAT (' ->',1X,I3)
      WRITE (8,1005)
      WRITE (6,1005)
      READ (5,1007) IVAR
      WRITE (8,4007) IVAR
4007  FORMAT (' ->',1X,I4)
      WRITE (8,1009)
      WRITE (6,1009)
      READ (5,1007) IVARS
      WRITE (8,4007) IVARS
C       FORMATS FOR PREPARATORY EFFORTS
1000  FORMAT(//'     FILE CONTAINING DATA IS IN FOLLOWING FORM:'//
     @  7X,'TITLE   (A60)'/
     @  7X,'NO. OF POINTS  (I5), TIME INCREMENT  (E16.8)'
     @  ' INITIAL TIME  (E16.8)'/7X,'AMPLITUDE  (5E16.8)'//
     @  '     IS THAT CORRECT?')
1002  FORMAT(A1)
1004  FORMAT('    LIST NUMBER OF LINES IN ALPHANUMERIC TITLE OF FILE'
     1 /'     (ONLY FIRST LINE IS SAVED AS TITLE), NO. OF LINES?')
1005  FORMAT ('  PROVIDE THE FORMAT FOR READING -NPT-, -DT-, T(1)'
     1  ' FOR EXAMPLE, (I5,2E16.8)')
1007  FORMAT (5A4)
1009  FORMAT ('    PROVIDE THE FORMAT FOR READING THE STRESS VALUES,'
     1  ' FOR EXAMPLE, (5E16.8)')
C
100   OPEN(UNIT=1,FILE=FILENAME,STATUS='OLD',ERR=900)
C *********                                                   *******
C               READ DATA
      IF (NLINES .GE. 1) READ (1,1008) IDENT
1008  FORMAT(A55)
      IF (NLINES .EQ. 0) WRITE (6,1011)
1011  FORMAT ('  ENTER TITLE FOR THE DATA')
      IF (NLINES .EQ. 0) READ (5,1008) IDENT
      IF (NLINES .LE. 1) GO TO 103
      DO 102 NL = 2,NLINES
102   READ (1,1008) NOTES
103   IDENT=IDAT//IDENT(1:40)
```

SUBROUTINE RECRED

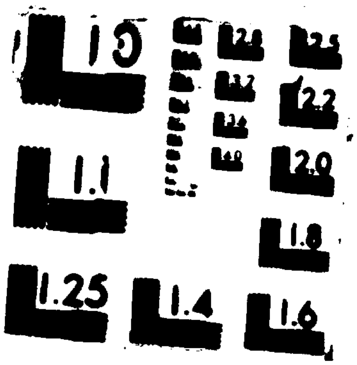
```
      WRITE (8,4008) IDENT
4008  FORMAT ('     ',A55)
      WRITE (6,1008) IDENT
      READ (1,IVAR) NPT,DT,TACTL(1)
      WRITE (8,4010) NPT,DT,TACTL(1)
4010  FORMAT ('      NPT =',I5,' DT =',1PE12.5,' T(I) =',E12.5)
      WRITE (6,1010) NPT,DT,TACTL(1)
1010  FORMAT (' NPT=',I5,' DT=',1PE12.5,' T(1)=',E12.5)
      READ (1,IVARS,END=910) (YACTL(I),I=1,NPT)
      DO 105 I=2,NPT
105   TACTL(I) = TACTL(I-1) + DT
      RETURN
C
C       ----------    ERROR FINISH  ------------------------------
900   WRITE (6,1090) FILENAME
1090  FORMAT(' ERROR IN OPENING ',A20)
      GO TO 950
910   WRITE (6,1092) FILENAME
1092  FORMAT(' END OF FILE ENCOUNTERED ON ',A20)
950   LS = 10
      RETURN
      END
```

SUBROUTINE RECRED (Concluded)

```
      SUBROUTINE REC1ST (LS,NPT,DT,TWINDO,TACTL,YACTL,NHIST,THIST,YHIST)
C
C     FIND LOCAL MINIMA AND MAXIMA IN THE -YACTL- RECORD.  CONSTRUCT A
C     RECORD FROM THESE MINIMA AND MAXIMA, STORING IT IN (YHIST, THIST).
C     NPT IS THE NO. OF POINTS IN THE YACTL RECORD, NHIST IS THE NO. IN
C     THE YHIST HISTORY.
C
      IMPLICIT REAL*4 (A-H,O-Z)
      DIMENSION TACTL(1),YACTL(1),THIST(1),YHIST(1)
      K=1
      YHIST(1)=YACTL(1)
      THIST(1)=TACTL(1)
      YMN=YACTL(1)
      YMX=YACTL(1)
      IBEG=2
      JEND = NPT
      IX=0
      IR=1
      YMOLD=YACTL(1)
      IXOLD=1
      DO 160 I=IBEG,NPT
      IF (I .LE. IXOLD) GO TO 160
      IF (IR) 115,130,108
C     MAXIMUM
108   IF (YACTL(I) .LE. YMX) GO TO 109
         YMX=YACTL(I)
         IX=I
         IR=1
         GO TO 160
109   IF (I-1 .NE. IX) GO TO 115
         M=TWINDO/DT+I-1
         JEND=MIN(M,NPT)
         I1=I
         I2=JEND
         DO 110 J=I,JEND
         IF (YACTL(J) .LE. YMX) GO TO 110
         YMX=YACTL(J)
         IX=J
  110    CONTINUE
         YMN=YMX
         YM=YMX
         GO TO 150
C     MINIMUM
115   IF (YACTL(I) .GE. YMN) GO TO 117
         YMN=YACTL(I)
         IX=I
         IR=-1
         GO TO 160
117   IF (I-1 .NE. IX) GO TO 130
         M=TWINDO/DT+I-1
         JEND=MIN(M,NPT)
         DO 120 J=I,JEND
         IF (YACTL(J) .GE. YMN) GO TO 120
         YMN=YACTL(J)
         IX=J
  120    CONTINUE
         YMX=YMN
         YM=YMN
         GO TO 150
C     EQUAL
```

SUBROUTINE REC1ST

AD-A183 528 ANALYSIS OF DYNAMIC IN SITU BACKFILL PROPERTY TESTS 2/2
REPORT 1 A METHOD FOR..(U) HEBREW UNIV JERUSALEM
(ISRAEL) L SEAMAN ET AL. JUL 86 WES/TR/SL-87-11-1
UNCLASSIFIED DCA39-83-K-0002 F/G 8/10 NL


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

```
130   IF (YACTL(I) .NE. YMOLD .OR. (I-IXOLD)*DT .LT. TWINDO) GO TO 160
         K=K+1
         YHIST(K)=YACTL(I)
         THIST(K)=(I-1)*DT+TACTL(1)
         IXOLD=I
      GO TO 160
150   K=K+1
      FRAC=0.5
      YHIST(K)=FRAC*(YM+YMOLD)
      THIST(K)=FRAC*(DT*(IXOLD+IX-2)+2.*TACTL(1))
      YMOLD=YM
      IXOLD=IX
      IX=0
      IR=1
      IF (IXOLD .EQ. I-1) GO TO 108
160   NHIST=K
      NHM=NHIST-50
      IF (NHIST .LE. 2001) RETURN
        WRITE (6,1094) NHIST
1094    FORMAT(' ***ERROR EXIT -- NO. OF ELEMENTS EXCEED ARRAY '
     1     'DIMENSION.'/5X,'NO. OF ELEMENTS,NHIST =',I5/
     2     'ARRAYS ARE DIMENSIONED 2001.')
        LS = 10
      RETURN
      END
```

SUBROUTINE REC1ST (Concluded)

```
      SUBROUTINE RUNG(IBUG,BETA,OMEGA,THIST,YHIST,NHIST,DT,IBEG,
     @   ISTOP,TACTL,YRCOMP)
      IMPLICIT REAL*4 (A-H,O-Z)
C        ROUTINE FOR CONDUCTING A 4TH ORDER RUNGE-KUTTA INTEGRATION OF
C        THE EQUATIONS OF MOTION OF A DAMPED ONE-DEGREE-OF-FREEDOM
C        SYSTEM.
C        BETA AND OMEGA ARE DAMPING FACTOR AND CIRCULAR FREQUENCY.
C        THIST AND YHIST ARE THE INPUT TIME AND POSITION POINTS FOR THE
C          FORCING FUNCTION.
C        YRCOMP IS THE OUTPUT MOTION, DEFINED AT NHIST TIME STEPS (DT).
C        NHIST IS THE NUMBER OF TIME STEPS IN THE FORCING FUNCTION.
C        DT IS THE TIME INCREMENT IN THE DIGITIZED RECORDS.
C        IBEG AND ISTOP DEFINE THE NUMBER OF DT TIME STEPS OVER WHICH
C        THE INTEGRATION IS TO OCCUR.
C
      DIMENSION THIST(1),YHIST(1),TACTL(1),YRCOMP(1),DYDT(4),DUDT(4)
C
      ISTART = MAX(IBEG-5,2)
      LI=1
      U0=0.
      Y0=0.
      IF (IBEG .LE. 2) GO TO 200
      Y0 = YRCOMP(ISTART-1)
      U0 = (YRCOMP(ISTART+1)-Y0)/(2.*DT)
200   DO 250 I = ISTART,ISTOP
      DO 210 L=LI,NHIST
      KI = L
      IF (THIST(L) .GT. (I-1)*DT+TACTL(1)) GO TO 220
210   CONTINUE
220   CONTINUE
      LI = KI
      YY=YHIST(LI-1)+(YHIST(LI)-YHIST(LI-1))*((I-1)*DT+TACTL(1)
     @  -THIST(LI-1))/(THIST(LI)-THIST(LI-1))
      COEF=0.5
      U=U0
      Y=Y0
      DO 230 J=1,4
      IF (J .EQ. 3) COEF=1.
      DYDT(J)=U
      DUDT(J)=OMEGA**2*(YY-Y)-2.*BETA*U
      U=U0+COEF*DUDT(J)*DT
      Y=Y0+COEF*DYDT(J)*DT
230   CONTINUE
      U=U0+DT/6.*(DUDT(1)+2.*(DUDT(2)+DUDT(3))+DUDT(4))
      Y=Y0+DT/6.*(DYDT(1)+2.*(DYDT(2)+DYDT(3))+DYDT(4))
      U0 = U
      Y0 = Y
      YRCOMP(I)=Y
250   CONTINUE
      RETURN
      END
```

SUBROUTINE RUNG

```
      SUBROUTINE VARIAN(YA,YC,IWINDO,JWINDO,V)
      IMPLICIT REAL*4 (A-H,O-Z)
C       COMPUTE THE VARIANCES BETWEEN THE YA (ACTUAL) AND YC (COMPUTED)
C       VALUES IN THE INTERVAL IWINDO TO JWINDO
      DIMENSION YA(1),YC(1)
      SUM=0.
      DO 100 I=IWINDO,JWINDO
      SUM=SUM+(YA(I)-YC(I))**2
100   CONTINUE
      V=SUM
      RETURN
      END
```

SUBROUTINE VARIAN

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